INSECT PESTS

of fruit and vegetables in NSW

Hely · Pasfield · Gellatley

INSECT PESTS

of fruit and vegetables in NSW

P C Hely
G Pasfield
J G Gellatley

Department of Agriculture New South Wales

Inkata Press
Melbourne, Sydney and I ondon

INKATA PRESS PROPRIETARY LIMITED
MELBOURNE, SYDNEY AND LONDON

PUBLISHED 1982
©Department of Agriculture New South Wales 1982

National Library of Australia card number and
ISBN 0 909605 27 0

All rights strictly reserved. No part of this book may be reproduced in any form without the permission in writing of the publisher.

Set in 9/10 Plantin by Savage & Co. Pty Ltd, Brisbane
Printed in Hong Kong

Designed by Pauline McClenahan

National Library of Australia
Cataloguing in Publication data

Hely, P. C. (P. Carl).
Insect pests of fruit and vegetables in New South Wales.

Includes bibliographies and index.
ISBN 0 909605 27 0.

1. Fruit — Diseases and pests — New South Wales.
2. Insects, Injurious and beneficial — New South Wales.
3. Vegetables — Diseases and pests — New South Wales.
I. Pasfield, G. (Gordon), 1919– . II. Gellatley, J. G. (John G.). III. Title.

634'.0497

Contents

Preface vii
Acknowledgements vii
Warning viii

Introduction 1
Safe and effective use of insecticides 4

CITRUS

Introduction 14
Citrus pests 22
References 83

POME FRUITS

Apple pests 91
Pear pests 116
Quince pests 120
Loquat pests 120
References 121

STONE FRUITS

Peach and nectarine pests 125
Almond pests 139
Plum and prune pests 140
Apricot pests 145
Cherry pests 147
References 151

GRAPE

Grape pests 154
References 168

TROPICAL FRUITS

Banana pests 172
Avocado pests 179
Macadamia pests 181
Pineapple pests 184
Passionfruit pests 186
References 190

MISCELLANEOUS FRUIT AND NUT TREES

Fig pests 194
Guava pests 197
Olive pests 198
Persimmon pests 199
Walnut pests 200
References 201

TRAILING BERRIES, BUSH FRUITS AND STRAWBERRY

Trailing berries and bush fruits pests 204
Strawberry pests 206
References 212

VEGETABLES

Introduction 216
Bean pests 218
Beetroot, silver beet and rhubarb pests 239
Carrot, parsnip, celery and parsley pests 243
Cruciferous pests 248
Cucurbit pests 259
Lettuce pests 266
Onion, shallot, leek, garlic and chive pests 270
Pea pests 273
Potato pests 277
Sweet potato pests 287
Tomato, capsicum and eggplant pests 290
References 301

Index 303

About the authors

The late Carl Hely, Gordon Pasfield and John Gellatley have, between them, a wide and detailed knowledge of the insect pests which affect agricultural production in New South Wales, including the best available natural or applied methods of controlling them. Their involvement in and knowledge of the investigations and services of the Entomology Branch of the New South Wales Department of Agriculture, from its foundation in 1890, undoubtedly qualifies them to be the authors of this book.

CARL HELY gained a diploma in agriculture (HDA) from Hawkesbury Agricultural College in 1924 before graduating as B.Sc.Agr. from the University of Sydney in 1929. In the same year he was appointed to the Entomology Branch of the NSW Department of Agriculture at Leeton. Having made major contributions to control measures for green peach aphid and California red scale, he moved to Gosford in 1933. Over 20 years he advanced significantly the knowledge of citrus and vegetable pests and their control, including important participation in the wartime food production effort. As deputy to the Chief Entomologist (1953–63) he continued research on citrus insect and mite pests as well as advising on a wide range of pest control problems.

He was Chief Entomologist from 1963 to 1967 and studied pest control research in India, Israel, Europe, England and USA. In the four decades spanned by Carl Hely's career great advances were made in economic entomology, and he could claim credit for a significant role in the development of control measures for agricultural pests, particularly citrus pests.

As a pioneer in the education of farmers, scientists and the public in appreciation of the value of insecticides and their safe and correct use, he recognised the need for a textbook on insect pests and their control. On his retirement in 1967, he started to bring together information on pests of fruit and vegetable crops and his information forms the foundations of this book.

GORDON PASFIELD graduated B.Sc.Agr. from the University of Sydney in 1941 and is widely experienced in economic entomology. He served the NSW Department of Agriculture from 1941 to 1975, the last eight years as Chief Entomologist.

During World War II he was involved in work on insect-borne diseases – the preparation of a key to Australian culicine mosquito larvae and later as the commander of a Malaria Control Unit of the AIF. In 1945 he began an investigation of the effects of newly-developed DDT on insect pests, with special attention to the control of codling moth, and noted the undesirable side effect of allowing an upsurge of two-spotted mite. Research into this and other methods of insect pest control on vegetables and in grape growing followed, and resulted in the successful control of thrips-transmitted spotted wilt virus on tomatoes.

After the discovery of Argentine ants in Sydney in 1950, Gordon Pasfield (with T. Greaves of CSIRO) developed an eradication technique, and later conducted successfully the experimental large-scale eradication campaign in the Sydney area. From 1962 to 1979 he directed the Government campaign to eliminate Argentine ants from New South Wales.

Having spent four years as deputy to the Chief Entomologist, he succeeded Carl Hely in the senior position in 1967. Gordon Pasfield reorganized the approach to insect pest investigations by placing greater emphasis on the understanding of a pest's relationship with its environment and on the minimization of environmental contamination by insecticides by first determining insecticide susceptibilities in bioassay tests in the laboratory. This also provided base data for monitoring the development of insecticide resistance by many insects. In 1970 he travelled extensively overseas.

He was entomological adviser on the Pesticides and Agricultural Chemicals Sub-committee of the National Health and Medical Research Council, served on the Standing Committee on Agriculture Entomology Committee of the Australian Agricultural Council, and was convenor of the Agricultural Entomology Section of the XIVth International Entomology Congress.

JOHN GELLATLEY joined the NSW Department of Agriculture in 1948 after graduating B.Sc.Agr. from the University of Sydney. Much of his wide experience of occurrence and control of insect and mite pests of citrus fruits and vegetables was gained from research at Gosford from 1951 to 1968. The citrus studies extended to most citrus-growing areas, and he became an authority on the pests of this crop.

Scale insect investigations included a long series of extensive orchard spraying experiments, before changes in marketing practices led to the use of natural enemies in scale control and the study of the efficacy of scale insect parasites in New South Wales. He also became experienced in Queensland fruit fly occurrence and control in the field as well as directing research into disinfestation treatments for fruits.

Since 1968 John Gellatley has been at the Biological and Chemical Research Institute, Rydalmere, where he has become familiar with all insect and mite pest occurrence and control study programmes in the State. In 1973 he visited USA and South Africa to study fruit disinfestation, control of fruit flies and the insect and mite pests of citrus. His work includes the production of the Entomology Branch's advisory bulletin series on agricultural pests and their control and aspects of pesticide registration and use.

He has served on the Technical Committee on Agricultural Chemicals, the Fruit Disinfestation Sub-committee of Standing Committee on Agriculture Plant Health Committee, and on the Exotic Insect Pests and the Insecticides Sub-committees of Standing Committee on Agriculture Entomology Committee. He was chairman of the entomology section for citrus at the XXth International Horticultural Congress in Sydney.

Preface

Food production throughout the world is significantly reduced by insect pests. The staff of the New South Wales Department of Agriculture's Entomology Branch, which was established in 1890, has made an outstanding contribution to the economic production of food in the State and to the well-being of its population. Their continuing research, over the years, has resolved most of the pest (insect and mite) problems in New South Wales, and it has been widely recorded in scientific journals in Australia and overseas. Results of investigations have also been summarized for farmers and the general public in the *Agricultural Gazette of New South Wales* and in a variety of information bulletins. In fact, the first scientific article in the first issue of the *Agricultural Gazette* in 1890 was one on codling moth submitted by the Government Entomologist.

This book brings together in an organized and systematic manner the achievements of the staff of the Entomology Branch in pest control on fruit and vegetable crops, since its inception, and it is a tribute to them. A considerable amount of the content of the book has not been published previously.

While this book is not concerned directly with pests of all agricultural crops, the insects and mites described would represent about 90 per cent of the significant crop pests of New South Wales, and thus most of those which are active throughout Australia. The knowledge of pests of fruit and vegetables is comprehensive, whereas much of the information on other agricultural crops is still to be evaluated due to the recent introduction of many new crops and cultural practices.

The need has long been recognized in New South Wales for a textbook on insect and mite pests of agricultural crops which describes the relationships between the pests, their natural enemies, their hosts and their environment, as illustrated by their significance, development, factors influencing abundance and control by natural and applied measures. The publication of such a book was a major objective of the late P. C. Hely, Chief Entomologist from 1963 to 1967; he retired from this position prematurely to write it. He prepared a large quantity of material, but his untimely death in 1969 prevented the completion of this ambitious project. It has been left to his successor (1967 to 1975), Gordon Pasfield, and to John Gellatley, Special Entomologist, to bring the book to publication after extensive and detailed amendment of the original text and incorporation of many recent developments in the knowledge of pests and their control.

The safe and effective use of insecticides for the many pests which are not susceptible to biological control has always been a guiding principle for the Entomology Branch. This has probably never been better demonstrated than in the 1940s by the action of the late T. McCarthy, Chief Entomologist (1939 to 1952), in deferring for some two years the recommendation of the outstanding new insecticide DDT as a control measure because of his views on the possible long-term harmful effects of DDT on man and animals. Carl Hely, with the encouragement of S. L. Allman, Chief Entomologist (1952 to 1963), adopted a positive stance on the correct use of insecticides. This resulted in publication by the Entomology Branch of the very comprehensive and practical Bulletin S62 *Insecticides – How to Use Them Safely and Effectively*. It was the first of its kind in Australia and one of the first in the world. One chapter of this book incorporates much of the content of this bulletin as well as some discussion of the State's legal requirements for the use of pesticides.

The major aim of this book is to inform and instruct a multifarious audience of primary producers, students, agricultural extension officers, entomologists and home gardeners. Maybe, it will act as well, amongst the world's ever-increasing mass of entomological literature, as a proud record of more than 90 years of effort in contributing to the world's entomological knowledge by the Entomology Branch of the New South Wales Department of Agriculture.

Acknowledgements

The authors are indebted to many people in the preparation of this book for publication, but particularly to Dr R. N. McCulloch, who was an entomologist in the Entomology Branch of the New South Wales Department of Agriculture before achieving distinction in other areas of public service. He carried out the initial editing to book size of Mr Hely's extremely large original manuscript.

The very competent typing of repeatedly amended copies of the manuscript is a tribute to the exceptional abilities of Miss C. Romano, Mrs B. Livet, Mrs C. Lomas and Mrs R. Valentine. We acknowledge the able assistance of Mr M. Hill, Mr J. Gasparotto and Mrs D. Lyon in preparing illustrations for inclusion in the book and of Mr R. Toffolon in preparing the maps.

It has given great pleasure to be able to publish many of the peerless colour illustrations of insect pests prepared in the 1950s by the late Mr E. H. Zeck prior to and immediately after his retirement from long service in the Entomology Branch. It is also appropriate to acknowledge here the fine artists who made line drawings of insects in the late nineteenth and early twentieth centuries, which have been used to illustrate this book.

Warning

In New South Wales it is an offence under the *Pesticides Act 1978* to use a pesticide contrary to the instructions on the registered label (unless a specific permit has been issued under the *Act* to do so).

As the legally approved instructions for use of individual pesticides may vary from time to time, irrespective of the recommendations in this book, it is essential to read, and follow, the registered label instructions.

Further assistance on recommendations can be obtained by contacting the New South Wales Department of Agriculture.

Introduction

Insect Pests of Fruit and Vegetables in New South Wales is concerned not only with insects (phylum Arthropoda, class Insecta) but also with mites (phylum Arthropoda, class Arachnida, order Acarina) which may occur as pests on fruit and vegetables in New South Wales. Mention is also made of some other pests, such as snails and slugs (phylum Mollusca, class Gastropoda, order Sigmurethra), because of their occasional importance and as the responsibility for their investigation and control is often accepted by entomologists. Mite pest species, although small in number, have particular significance as they not only cause direct damage but also because there is an established link, in some cases, between their abundance and the use of certain insect pest control measures.

The scientific names of the pests described are as defined by *Scientific and Common Names of Insects and Allied Forms Occurring in Australia* compiled for the Standing Committee on Agriculture – Entomology Committee by P. B. Carne, L. D. Crawford, M. J. Fletcher, I. D. Galloway and E. Highley (Commonwealth Scientific and Industrial Research Organisation, 1980) where applicable, or as in *The Insects of Australia* (CSIRO, 1970), or as advised by a recognized authority. The last case is particularly relevant to the names of parasites and predators. The names of the authors of specific insects is quoted only in the lists at the beginning of the sections, or wherever the specific name is first mentioned in the text. Common names for the insects and allied forms are as quoted in *Scientific and Common Names* except that the method of compounding words has mostly not been adopted.

Names of insecticides, miticides and fungicides used in the book are from *Standards Association of Australia Recommended Common Names for Pesticides*, where available.

The material from which the book has been compiled is based to a very great extent on the observations and investigations of entomologists of the New South Wales Department of Agriculture, but there were instances where the information available in New South Wales was incomplete. In such cases it has been supplemented by acknowledged information from other State organizations, particularly the Entomology Branch of the Queensland Department of Primary Industries concerning pests of tropical fruits and some vegetables, and CSIRO. Research in other countries is also referred to in order to illustrate points made with reference to local pests.

However, a general review of the world's literature on pests of fruit and vegetables, particularly that of about the last fifteen years, has been largely avoided because it was considered that the controversial nature of much of this material might have tended to harm the objectivity of presentation aimed at by the authors. The comprehensive knowledge of the habits and behaviour of the pests which is presented in this book will provide a sound basis for the development of satisfactory integrated control methods. Such methods will depend less on the application of chemicals and will thus have less effect on the environment.

Efficient and safe chemical control measures are facing the serious challenges of increasing insecticide resistance and the costliness of production of new pesticides which leads to a diminution of availability. The era of almost total dependence on

pesticides is ending and the provisions of legislation, such as the New South Wales *Pesticides Act 1978*, will ensure that they are used much more selectively. However, pest problems are not diminishing and dealing with them effectively will demand a wealth of information on the pests concerned.

Details of the control measures using pesticides have been kept to a minimum, despite their importance, because this book does not aim to become a substitute for a pest control guide as recommendations and application techniques can soon become outdated. It must be stressed that **no applied control measure in this book should be adopted without first referring to the Department of Agriculture for the latest recommended control measure**. The control measures described are merely illustrative of the contemporary methods of overcoming pest problems. Until the advent of the *Pesticides Act 1978*, the Entomology Branch of the New South Wales Department of Agriculture had based its pest control recommendations on successful field experiments by its own officers or, when experimental evidence had been unavailable within a reasonable time, on the observations of its most experienced officers in the field. Environmental safety was always a major consideration in arriving at a decision on control measures. Over the years these recommendations have never harmed the user, the crop, the consumer or the environment.

The methods of application of pesticides, as well as the equipment used, have been undergoing considerable changes in the last ten to fifteen years. These have tended to coincide with changing cultural practices which in turn have made possible the use of methods which could not have been employed previously.

For the convenience of the reader of this book it has been structured as far as possible to follow a uniform pattern. Each section is concerned with a crop or related group of crops – citrus; pome fruits; stone fruits; grapes; tropical fruits; miscellaneous fruit and nut trees; trailing berries, bush fruits and strawberry; and vegetables. Within the related groups the pests of individual crops, such as apples, bananas, macadamia nuts, currants, tomatoes or peas, are described separately. References are listed at the end of each section.

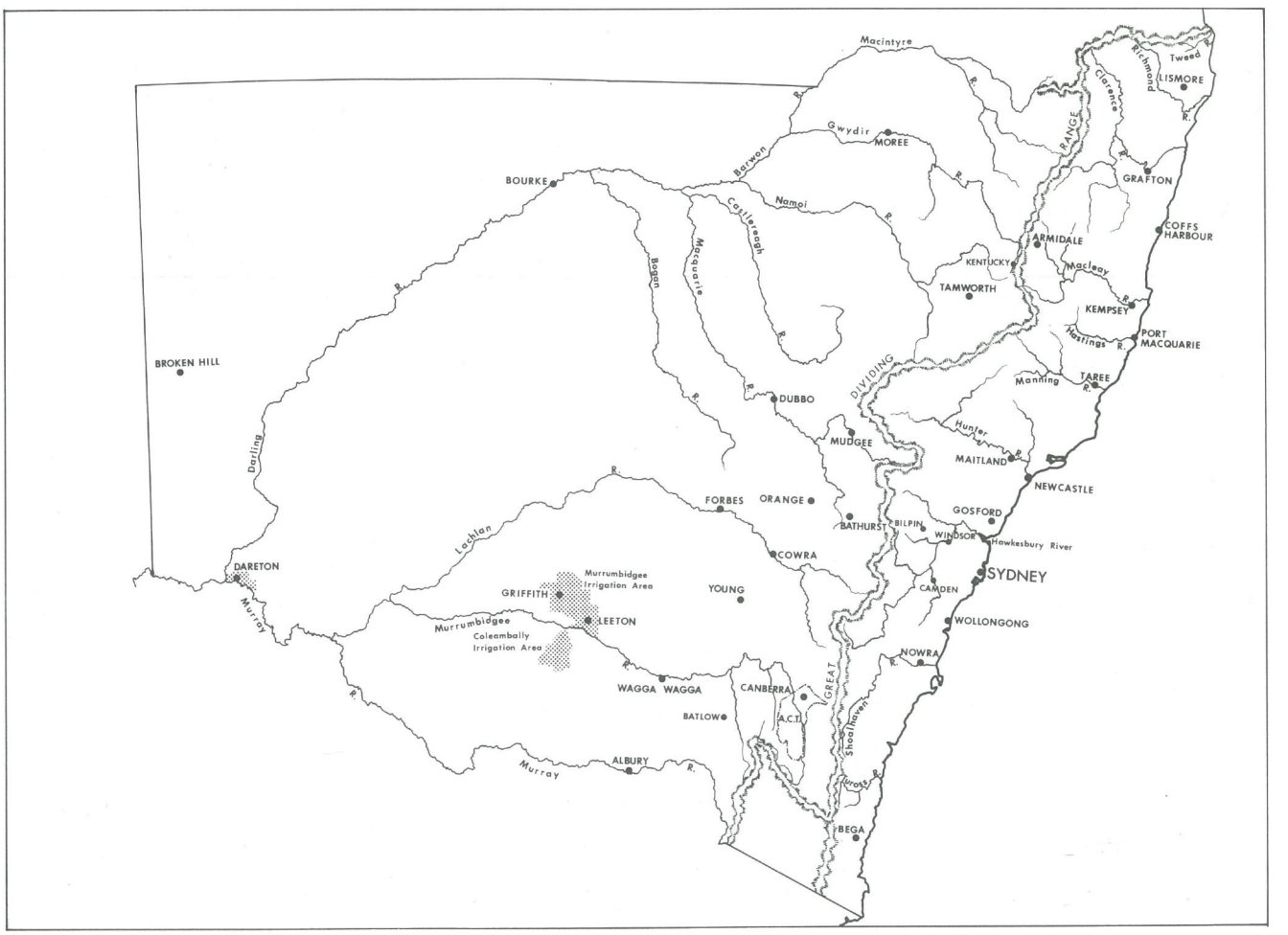
The pests of each crop or group of crops are presented in a uniform sequence of zoological orders – Lepidoptera (moths and butterflies), Hymenoptera (wasps, ants and sawflies), Diptera (flies and midges), Coleoptera (beetles), Thysanoptera (thrips), Hemiptera (bugs, scale insects and aphids), Orthoptera (crickets, grasshoppers and locusts), Acarina (mites) and, occasionally, other pests of different phyla. A full list of the pests of most of the crops is given after an introductory description of the crop, and is usually arranged in degree of importance within each order. These lists may be divided into two parts: one in which the pests are described as fully as possible for that specific crop and one in which the pests are described more fully under other crops. The sequence of pest descriptions follows the order in the lists. It should be noted, however, that the lists at the beginning

of the sections dealing with pome and stone fruits are in alphabetical order, but revert to the order of importance for each of the crops in these two groups. As the pests are described under order headings, the sequence does not necessarily represent the degree of importance for each crop, which may, of course, vary also on a State wide basis. For those pests on which more detailed information is available, a uniform format of headings has been adopted which includes: importance and distribution, conditions for infestation, plants attacked, description and life history, injury, dispersal and control measures (natural and applied). In other cases a short description, without headings, is given and reference is often made to another crop or crops under which the pest is described in greater detail.

There is considerable variation in the number and importance of pests associated with individual crops. The section on citrus pests occupies almost one-third of the book, mainly because citrus harbours a much greater number of pests than any other crop; the evergreen nature of citrus encourages permanent insect populations. This has stimulated very intensive studies over some 60 years in New South Wales of the inter-relationships of pests with the various host varieties, of pests with natural enemies and of pests with each other. Specific spraying practices have been developed which are very necessary in such complex host-pest relationships. These studies have led also to a greater detailed knowledge of citrus culture and the opportunity has been taken in the book to enlarge upon this.

The classification of miscellaneous fruit and nut trees was chosen for convenience in the presentation in this book and is not based on horticultural criteria. The crops in this classification have been presented alphabetically, but classifications of other combined crops have not necessarily been presented in the same way. Vegetable crops are in alphabetical order, but allowance must be made for combinations of crops, such as beetroot, silver beet and rhubarb; carrot, parsnip, celery and parsley; onion, shallot, leek, garlic and chive; and tomato, capsicum and eggplant. Potato and tomato, although both are solanaceous crops, were not combined because of their different growth culture and habits, and the differences in their major pests.

Following the publication of the article 'Notes on Introduced Slugs of the Families Limacidae and Milacidae in Australia with Two New Records' (*J. Malac. Soc. Aust.,* **3(2)**: 63–80. 29 Aug. 1975) by C. O. van Regteren Altena and B. J. Smith, it was discovered that Entomology Branch records were insufficient for differentiation between the species, so the three possible species are listed wherever slugs have been mentioned as pests. Records of specific identifications of wireworms and false wireworms were also not available for inclusion in the book, so they have been grouped together wherever mention is made of wireworms.



Safe and effective use of insecticides

Insecticides, which in this chapter include acaricides, are used on fresh fruits and vegetables to ensure adequate yields of high-quality produce. Most fruits and vegetables are attacked by pests that can cause severe reduction in yields by damaging plant growth. The produce may be blemished, unattractive or even totally destroyed, or debilitating virus diseases of plants may be transmitted.

Despite some success with biological and other non-chemical methods of control, the use of insecticides still remains the major method of protection against the depredations of insect pests on crops, both in the field and in storage. However, to meet the changing demands of a better-informed community, continuing research into more efficient pest management is essential. In any case, there is a constant review of such matters as the determination of more efficient and economical insecticides, improvements in their application, the challenges posed by resistance of insects to insecticides, and restrictions on insecticide use arising from changing attitudes to occupational exposure and acceptable levels of residues on marketable produce and in the environment.

Many insecticides, designed as they are to be detrimental to certain life forms, may also be harmful, if used incorrectly, to man or to the environment. **Safe use is just as essential as efficacy**. Consequently, the ways in which insecticides will be used are closely considered before approval is given by health and agricultural authorities. In New South Wales there are legal requirements for both the marketing and the use of insecticides.

The use of insecticides is considered under the eight headings listed below.

- ☐ Types of insecticides
- ☐ Safe use
- ☐ Precautions
- ☐ Symptoms of poisoning
- ☐ Hazards to fish, birds and bees
- ☐ Residues and withholding periods
- ☐ Effective use
- ☐ Legal requirements

Orchard spraying. The driver is wearing protective clothing.

Types of insecticides

Most of the insecticides used currently are synthetic compounds belonging to the organophosphorus, carbamate, organochlorine or pyrethroid groups, or are acaricides (miticides) of various chemical groups. While individual insecticides have some characteristics in common with others in the same chemical group, they can vary widely in effectiveness against particular pests and in their toxicities to other organisms. The active ingredients of insecticides are usually referred to by standard common names which are accepted internationally. The characteristics of many of the insecticides mentioned below are discussed by Martin (1969) and Ware (1978).

Organophosphorus compounds The organophosphorus insecticides vary from very high to low in their level of acute toxicity to man and, therefore, in their degree of hazard to the user, but they neither accumulate in animal body fat nor leave persistent residues in the environment. They usually kill insects by contact and have a limited residual effect against chewing insects. Several can penetrate fruit to kill insects. Some are systemic in action, being absorbed from sprayed foliage or treated soil to enter the sap-stream of the plant. These are mainly effective against sap-feeding pests, such as aphids and thrips, but not against scale insects when used at normal concentrations.

Organophosphorus insecticides currently in use in fruit and vegetable growing include acephate, azinphos-ethyl, azinphos-methyl, carbophenothion, chlorfenvinphos, chlorpyrifos, demeton-S-methyl, diazinon, dimethoate, ethion, fenthion, formothion, maldison, methamidophos, methidathion, mevinphos, monocrotophos, naled, parathion, parathion methyl, phosmet, phosphamidon, pirimiphos-ethyl, thiometon, trichlorphon and vamidothion.

Carbamates The carbamate insecticides used on fruits and vegetables at the present time do not leave persistent residues in the environment and do not accumulate in animal fat. They include aminocarb, carbaryl, methomyl, pirimicarb and promecarb. The carbamate methiocarb is used in snail control, and some dithiocarbamate fungicides, such as zineb, are effective against eriophyid mites.

Organochlorines Most of the organochlorine insecticides have long-lasting effectiveness against certain susceptible pest species, but they may be absorbed by and accumulated in animal body fat and leave persistent residues in the environment. DDT and lindane, as well as the cyclodienes – aldrin, chlordane, dieldrin, endrin and heptachlor – for which there are no accepted tolerances as residues in meat or milk products, have these characteristics so their recommended uses are greatly limited. Endosulfan does not cause problems in this way.

Pyrethroids Several synthetic pyrethrin-like insecticides have been developed that are stable in sunlight, unlike the botanical insecticide pyrethrin, and highly effective against some agricultural pests, particularly caterpillars. Fenvalerate and permethrin are examples of these insecticides.

Acaricides Most of these compounds are specific against mite pests and have low toxicity to humans. They act by contact and must be applied thoroughly. Acaricides currently used include azocyclotin, binapacryl, bromopropylate, cyhexatin, dicofol, fenbutatin oxide, oxythioquinox, propargite and tetradifon.

Other materials for insect and mite control These include inorganic sulphurs (sulphur spray or dust, or lime-sulphur spray), plant extracts (for example, rotenone, the active ingredient in derris), petroleum oils (summer or winter use types), inorganic salts (for example, lead arsenate), soap and soda solutions, and a product formulated from the spores of the entomogenous bacterium *Bacillus thuringiensis* for use against certain caterpillar pests.

Safe use

Insecticides vary widely in toxicity to man and animals – from relatively safe to highly toxic, but none will constitute a hazard **if used correctly**. Before making recommendations or approving claims made on the label of an insecticide product offered for sale, the Department of Agriculture must be satisfied that the pesticide, when used as directed, will be safe to the user, the consumer and the environment generally, as well as being effective. All pesticide products (including insecticides and acaricides) marketed in New South Wales must be labelled, and give appropriate directions for safe and effective use on the label. These labels are checked each year. **The necessity of reading labels carefully cannot be stressed too strongly.**

Most poisonings by insecticides are occupational accidents suffered by spray operators, and they usually occur through contamination with the pesticide concentrate. Insecticide concentrates, like many other poisonous substances used in the home or on the farm, may also be ingested accidentally, mainly by children. Commonsense precautions and a knowledge of the product provide the best basis for safe use.

Insecticides may be disabling to man and, in extreme cases, may be fatal. They can enter the body in several ways:

- ☐ when swallowed (oral toxicity);
- ☐ by penetration through the skin (dermal toxicity), the most common hazard to spray operators; and
- ☐ when inhaled (respiratory toxicity), a serious danger in enclosed buildings when fumigant gases, or sprays with fumigant action, are used.

The hazard in using an insecticide varies with its toxicity, the degree of exposure to it and the predisposition of the individual.

Toxicity The amount of toxic material, expressed in milligrams of material per kilogram of bodyweight, which causes the death of 50 per cent of animals in a test cage is called the LD_{50}. The oral LD_{50} is measured by feeding the material to the animals and the dermal LD_{50} by applying it to their skin. Thus, the lower the value of the LD_{50} the more toxic the pesticide may be. The application of these toxicity figures to human poisoning is only approximate as they have been determined using animals. Data assembled by the Health Commission of New South Wales (Anon, 1976) are presented in Table 1.

Exposure The effects of exposure to an insecticide are proportional to its duration and to the amount of unprotected body surface presented by the spray operator to spray contamination. Minimal exposure will be achieved by adhering strictly to the precautions specified for the use of a particular insecticide.

Predisposition An unprotected operator may have been adversely affected, unknowingly, by recent use of organophosphorus sprays and therefore will be more readily affected by further spraying. Regular testing for blood cholinesterase levels

Table 1 Acute toxicity data and hazard gradings for some insecticides and acaricides used in fruit and vegetable growing

Insecticide	Chemical group[1]	Oral LD_{50} (mg/kg)	Hazard grading[2] (oral)	Dermal LD_{50} (mg/kg)	Hazard grading[2] (dermal)
aminocarb	C	30–38	xxx	275–280	xx
azinphos-ethyl	OP	9	xxx	280	xx
azinphos-methyl	OP	7–13	xxx	280	xx
binapacryl		58–225	xx	720–810	xx
bromopropylate		5000	x	>4600	x
carbaryl	C	400	xx	>500	xx
carbophenothion	OP	7–30	xxx	800	xx
chlordane	OC	283	xx	>1600	x
chlorfenvinphos	OP	10–155	xxx	30–108	xxx
chlorpyrifos	OP	82–163	xx	202	xx
DDT	OC	300–500	xx	2500	x
demeton-S-methyl	OP	57–106	xx	303	xx
diazinon	OP	300–600	xx	500–>1200	xx
dicofol		575–>2000	x	100–1230	xx
dieldrin	OC	40	xxx	>100	xx
dimethoate	OP	200–300	xx	700–1150	xx
endosulfan	OC	35	xxx	74–680	xxx
endrin	OC	3–6	xxxx	60–120	xxx
ethion	OP	13–34	xxx	1600	x
fenitrothion	OP	130–200	xx	700	xx
fensulfothion	OP	2	xxxx	3–4	xxxx
fenthion	OP	200	xx	1300	x
formothion	OP	400	xx	400–1680	xx
heptachlor	OC	40	xxx	195–250	xx
lindane	OC	230	xx	500–1000	xx
maldison	OP	1400–1900	x	>4000	x
methamidophos	OP	30	xxx	50–110	xxx
methidathion	OP	20–48	xxx	25–400	xxx
methiocarb	C	60–135	xx	>2000	x
methomyl	C	27	xxx	>1600	x
mevinphos	OP	3–5	xxxx	90	xxx
monocrotophos	OP	13	xxx	122	xx
naled	OP	250–430	xx	800–1100	xx
nicotine		70	xx	140	xx
omethoate	OP	50	xxx	700	xx
oxythioquinox		1100–3000	x	1000	xx
parathion	OP	3–6	xxxx	4–35	xxxx
parathion methyl	OP	12–16	xxx	67	xxx
phosmet	OP	113–245	xx	2550	x
phosphamidon	OP	15	xxx	125	xx
pirimiphos-ethyl	OP	126–152	xx	1000–2000	x
promecarb	C	35	xxx	450–>2000	xx
pyrethrins		570	x	>1350–5400	x
rotenone		25–132	xxx	>940–>3000	xx
tetradifon		566	x	>10,000	x
thiometon	OP	100	xx	>200	xx
trichlorphon	OP	650	x	>2800	x
vamidothion	OP	64–100	xx	1160	x

[1] C – carbamate
OP – organophosphorus
OC – organochlorine

[2] Tentative scheme of hazard gradings:

		LD_{50} (mg/kg) *Oral*	*Dermal*
xxxx	extremely hazardous	<5	<10
xxx	highly hazardous	5–50	10–100
xx	moderately hazardous	50–500	100–1000
x	slightly hazardous	>500	>1000

in persons exposed to these compounds makes it possible to anticipate the occurrence of symptoms and prevent further exposure before symptoms occur.

Although some organophosphorus compounds are in themselves relatively safe to use it may be dangerous to apply them shortly after the use of other highly toxic organophosphorus substances. Thus, for example, maldison should be used with great care following recent spraying with mevinphos. This phenomenon of 'potentiation' is of considerable importance when using these chemicals.

Precautions

Protective clothing should be worn to protect against skin absorption whenever insecticides are handled and used for spraying. This is the most likely means of poisoning, as most insecticides can be absorbed through the skin. The very least protective clothing should include a cotton boiler suit buttoned up at wrists and throat, washable hat, and impervious gloves and footwear. A waterproof cape and an agricultural-type respirator should also be used during concentrate spraying, or in dilute spraying if the operator is continually exposed to heavy spray drift.

Spray operators are most often imperilled by insecticide concentrates when they are preparing vats of spray. These must be handled carefully to avoid gross contamination through splashing or spillage. Any contamination that occurs should be washed off immediately with soap and water. Wettable powder concentrates are especially likely to contaminate the operator during the weighing out and initial preparation of the spray. When premixing wettable powder spray, tip it gently on to the water and allow it to sink before stirring. Goggles and a respirator should be worn when measuring or diluting insecticide concentrates, although a face shield is usually sufficient for liquid concentrate. This equipment should be protected from contamination when not being worn.

Operators should use spraying techniques which avoid long and repeated contamination by spray drift. When accidentally doused with insecticide from burst spray hoses, they must wash immediately and change their clothing. Ample washing facilities should be available to remove contamination when these accidents occur and for use before eating or smoking; soap and water is the best means of decontamination. Operators should change and wash their clothing at the end of each day's work.

As illustrated in Table 1, the toxicities of insecticides cover a wide range. **Highly toxic insecticides should be used only by persons thoroughly familiar with their hazards.**

Working in sprayed areas should be avoided, as far as possible, for a few days.

Insecticides should be stored in a locked shed, and kept only in the original labelled containers. Leakage from the containers requires immediate attention, such as by absorbing it on sawdust-lime mixture and then removing it.

Empty insecticide containers should be cleaned out thoroughly, carefully avoiding any contamination of the surroundings, crushed and buried. Paper and plastic bags and cartons should be burnt, but inhaling the smoke must be avoided.

Neither a naked flame nor an electric torch should be used to illuminate the interior of a spraying vat because a violent explosion may occur due to the presence of flammable solvent vapour freed from the diluted emulsifiable concentrate spray. These explosion accidents have occurred occasionally.

Symptoms of poisoning

The Health Commission of New South Wales bulletin *Poisoning by Pesticides* (Anon, 1976) was prepared to assist medical practitioners and others who may have to deal with cases of poisoning, as well as to guide users of pesticides in the prevention of poisoning. It describes symptoms of insecticide poisoning as follows:

Organophosphorus compounds The first symptoms of poisoning by these come on within minutes, or, at most, a few hours after exposure. They are usually headache, fatigue, giddiness, salivation, sweating, blurred vision and pin-point pupils, chest tightness, nausea, abdominal cramps and diarrhoea. Development of such symptoms in an exposed person is an indication for seeking urgent medical aid. Symptoms may not reach the maximum until 4–8 hours after onset and may gradually diminish over 1–6 days. Occupational poisoning generally occurs from skin contamination. However, if concentrate of any of the more toxic organophosphorus compounds, such as parathion or mevinphos, is splashed in the eye, absorption may be very rapid. If swallowed, organophosphorus materials are rapidly absorbed from the stomach. In the case of massive exposure, death may occur in a few minutes.

Carbamates The toxic effect of carbamates is very similar to that of organophosphorus compounds (although treatment is not identical).

Organochlorines Most compounds in this group, except DDT, can be absorbed through the skin. The chlorinated hydrocarbons are cerebral convulsants. The first symptoms are restlessness and increased excitability, and these may be followed by muscular twitching of a localised character which increases in violence; finally the victim may develop a 'fit', not unlike that of epilepsy. Symptomatology depends upon dosage and rate of absorption.

It is advised that medical attention should be obtained as quickly as possible if symptoms of poisoning develop, or if gross contamination of skin or eyes by a concentrate of toxic material occurs, or if insecticide is swallowed. Follow the first-aid instructions on the label of the insecticide container while awaiting medical attention, remove contaminated clothing, and wash the affected skin or eyes thoroughly.

Hazards to fish, birds and bees

Insecticides should be applied only to specific pests on specific crops, and the applications should be limited to the target area. Persistent insecticides must be limited to situations where an acceptable non-persistent alternative is not available.

Fish They are highly susceptible to organochlorines even in minute concentrations. The toxicities of organophosphorus compounds and carbamates to fish are variable and may range, for example, from very high for azinphos-methyl to very low for dimethoate. Application of insecticides near fish ponds, lakes and streams requires special consideration; the least hazardous insecticides at minimum effective doses should be used in such locations only with special precautions to avoid water contamination by spray drift, run-off or spillage. While insecticide seepage through the soil to water is not a problem, contamination of

water by erosion of contaminated soil could be hazardous. Farm dams and ponds should be protected by a grassed area at least 20 metres wide.

Birds Poultry and other birds are particularly susceptible to poisoning by certain insecticides, so spraying in their vicinity must be done with great care. Precautions listed on the label must be carefully observed when spraying near to their food.

Bees These insects can be killed by toxic chemicals, and field bees may contaminate and even kill whole hives by introducing insecticides picked up on their bodies while working flowers. Spray or dust drift puts bees at risk in hives or on flowers. Other hazards to bees could be contaminated flowering weed or cover crops in orchards, or contaminated water.

Beekeepers should be given adequate warning before large areas are sprayed so that they may remove hives to a safe place or shut in their bees. Insecticide should generally be applied in the early morning, late evening or night, when bees are not active.

Johansen (1969) considered residual action to be the key factor in determining which chemicals could be applied safely to crops in bloom and proposed that pesticides with moderate to high residual toxicity – ten hours or more after spraying – cannot be applied safely to flowering crops at any time. Using data from Johansen and from Anderson *et al* (1971), insecticides are grouped below in categories of highly, moderately and least toxic to bees.

HIGHLY TOXIC Aminocarb, azinphos-ethyl, azinphos-methyl, carbaryl, chlordane, chlorfenvinphos, chlorpyrifos, diazinon, dieldrin, dimethoate, fenitrothion, fenthion, heptachlor, lead arsenate, lindane, maldison, methamidophos, methidathion, methomyl, mevinphos, monocrotophos, omethoate, parathion, parathion methyl, phosmet and phosphamidon.

MODERATELY TOXIC (If not applied directly to bees in the field or on the colonies.) Carbophenothion, demeton-S-methyl, DDT, endosulfan, endrin, ethion, naled, thiometon and trichlorphon.

LEAST TOXIC *Bacillus thuringiensis*, binapacryl, dicofol, oxythioquinox, nicotine sulphate, pirimicarb, pyrethrins, rotenone, sulphur and tetradifon.

Residues and withholding periods

Maximum permissible levels are stipulated for residues of insecticides on marketed produce. Such levels are usually those which are likely to result from correct use of the insecticides – provided that they are far below the levels assessed by health authorities as potentially harmful to the consumer. Also stipulated is the minimum time, or withholding period, which should elapse between spraying and harvesting so that the insecticide residue will not exceed the maximum level. The withholding period and maximum residue level are specified for each insecticide use pattern; both are subject to change as more information is gained on the significance and durability of the residue of the particular insecticide, and this frequently leads to the specification of a reduced withholding period. For some insecticides the withholding periods can be extremely brief, but for others they may be several weeks (Table 2). **Withholding periods are not indicators of toxicity to humans.**

Table 2 Examples of withholding periods

Insecticide	Crop	Typical withholding period[1]
acephate	tomato	3 days
aminocarb	pome fruit	3 days
azinphos-ethyl	potato	2 weeks
azinphos-methyl	pome and stone fruit	2 weeks
Bacillus thuringiensis	cruciferous crops	not required
binapacryl	pome and stone fruit	3 weeks
bromopropylate	pome and stone fruit	3 weeks
carbaryl	fruits, vegetables	3 days
carbophenothion	pome and stone fruit	3 weeks
chlorfenvinphos	potato	1 day
chlorpyrifos	tomato	3 days
cyhexatin	pome and stone fruit	2 days
DDT	vegetables	4 weeks
demeton-S-methyl	pome and stone fruit, tomato	3 weeks
diazinon	vegetables	2 weeks
dicofol	vegetables	7 days
dimethoate	fruits, vegetables	7 days
endosulfan	pome and stone fruit tomato	2 weeks 7 days
ethion	citrus	3 weeks
fenthion	pome and stone fruit, citrus, tomato	7 days
formothion	pome and stone fruit, tomato	7 days
lindane	apple	4 weeks
maldison	fruits, vegetables	3 days
methamidophos	potato	7 days
methidathion	citrus pome and stone fruit vegetables	3 weeks 2 weeks 7 days
methomyl	tomato	1 day
mevinphos	pome and stone fruit, vegetables	2 days
monocrotophos	apple, pear	4 weeks
naled	cruciferous crops, tomato	1 day
omethoate	citrus, pome fruit	7 days
oxythioquinox	pome and stone fruit	2 weeks
parathion	pome and stone fruit, vegetables	2 weeks
parathion methyl	pome and stone fruit, vegetables	2 weeks
petroleum oil	citrus	1 day
phosmet	citrus, pome fruit	3 weeks
phosphamidon	vegetables	3 weeks
pirimicarb	apple, stone fruit	2 days
promecarb	citrus	2 weeks
propargite	apple	7 days
rotenone	potato	1 day
tetradifon	fruits, vegetables	7 days
thiometon	fruits, vegetables	3 weeks
trichlorphon	vegetables	2 days
vamidothion	pome fruit	6 weeks

[1] **Always follow product label advice.**

Effective use

This may best be considered under the headings, formulation, spray dosage, preparation and agitation of sprays, combination of sprays, spraying, timing, weather and phytotoxicity.

Formulation Most insecticide concentrates used on fruit and vegetable crops are formulated as either an emulsifiable concentrate or a wettable powder. In emulsifiable concentrates the active constituent is dissolved in a solvent, such as toluol, usually with the addition of an emulsifier and a wetting agent. In wettable powders the active constituent and a wetting agent are incorporated on to an inert powder, such as pyrophyllite.

Insecticides are also formulated as dusts diluted with an inert powder. These are used mainly in home gardens due to their convenience for small-scale use.

Spray dosage Insecticides which are formulated ready for use are marketed under brand names, but the label gives the standard common name and content of the active constituent – expressed for emulsifiable concentrates as grams per litre and for wettable powders as grams per kilogram.

Recommendations for conventional spraying of fruit trees and small areas of vegetables are usually expressed as a percentage of the active constituent in the diluted spray. For example, 0.05 per cent maldison could be made up from either 100 millilitres of maldison emulsifiable concentrate of 500 grams per litre content, or 200 grams of maldison wettable powder of 250 grams per kilogram content, in 100 litres of water. Table 3 gives guidance for calculating dilution rates. However, appropriate instructions about dilution rates are given on product labels.

For spraying large areas of vegetables the recommendation is commonly expressed as active constituent (a.c.) per hectare. For example, treatment with dimethoate at 330 grams a.c. per hectare is achieved with 1.1 litres of dimethoate 300 grams per litre emulsifiable concentrate applied, suitably diluted, per hectare.

Preparation and agitation of sprays

Follow the directions on the product label. Some spray concentrates need to be pre-mixed with a small amount of water before being added to the bulk of the water in the spray vat. When premixing wettable powders, add the powder to the water and allow it to sink before stirring. Do not place the spray materials in the vat until immediately before the spray is to be used. Good agitation in the spray vat is essential for most spray materials.

Combination of sprays

Some spray materials can be mixed together, but some combinations are unsatisfactory – particularly those with alkaline sprays, such as lime-sulphur or Bordeaux mixture. Compatibility charts for spray combinations are available for guidance, but always follow the instructions on the product label. The mixing of emulsifiable concentrates with wettable powders is considered to be undesirable.

Spraying Thorough coverage with spray is usually needed over the affected parts of the plant, other than when using certain systemic insecticides. In high-volume spraying, a well-grown apple tree might need 20 litres of spray material and a mature citrus tree sprayed for California red scale control might need 50 litres or more.

Spray application methods should be matched to the habits of the pest and the properties of the insecticide. For example, San José scale infests tree trunks, branches and laterals, and it is often beneath loose bark, so its control by contact insecticides requires carefully-directed full-coverage spraying. Control of aphids on tree foliage, however, can be achieved by systemic insecticides with only moderate-coverage spraying using drive-past spraying methods.

Timing Correct timing of spraying is often most important, either for greater efficacy or to decrease spray injury risk. The timing of routine control measures against regular pests is often determined by plant growth stages or by the stage in the life cycle of the pest. Some spraying can be done only when the pests appear, but preferably before their numbers build up.

Weather Spraying in strong winds is inefficient and wasteful and may also be hazardous, but a slight breeze is an advantage and helps to dry sprays quickly. Where foliage is wet with rain or dew, delay spraying until the plants have dried. Rain falling on trees after spraying, and before the spray deposit has dried thoroughly, might make the treatment ineffective. Do not spray

Table 3 Dilution table – for the preparation of 100 litres of spray

	Strength of concentrate (active constituent content, as grams per litre or grams per kilogram)							
	150	200	250	300	400	500	800	1000
Required strength of dilute spray (percentage active constituent)	Millilitres or grams of concentrate to be made up to 100 litres with water							
0.1	670	500	400	330	250	200	125	100
0.075	500	380	300	250	190	150	94	75
0.06	400	300	240	200	150	120	75	60
0.05	330	250	200	170	125	100	63	50
0.04	270	200	160	130	100	80	50	40
0.03	200	150	120	100	75	60	38	30
0.025	170	130	100	83	63	50	32	25
0.02	130	100	80	66	50	40	25	20

in very hot weather, or in frosty conditions, or when the soil is very dry, because of the risk of plant injury.

Phytotoxicity Some insecticide sprays can be harmful to certain plant species, or to certain cultivars within a species; either the insecticide chemical itself or a component of the formulation may be responsible. This injury can take the form of leaf scorching, leaf- or fruit-fall, and fruit marking. Thorough testing for these effects is essential during the development of new insecticide use patterns. Some examples of plants harmed by certain insecticides are: early varieties of stone fruits by certain organophosphorus insecticides; fig, kumquat, Meyer lemon and Seville orange by dimethoate; and Delicious apple is very susceptible to fruit marking by emulsifiable concentrate sprays.

Apart from specific susceptibilities such as these, spraying injury when using an insecticide which is normally satisfactory can be due to such factors as: unsatisfactory preparation of the diluted spray, inadequate agitation in the spray vat, incompatible spray material combinations, reaction in the spray vat with a residue of previously-used material, over-application of spray, or unsuitable weather conditions for spraying (too hot, or too cold for satisfactory drying of the spray, or in frosty conditions) or when soil is very dry.

Legal requirements

In New South Wales, the use of pesticides in fruit and vegetable growing is subject to the requirements of the *Pesticides Act 1978*, the *Pure Food Act 1908 (as amended)*, the *Poisons Act 1966* and the *Public Health Act 1902*.

Pesticides Act 1978 This legislation includes direct control over use of pesticides in addition to its other requirements. It has replaced the *Pest Destroyers Act 1945*. Proprietary pesticide products are registered by the New South Wales Department of Agriculture before their sale and use for the purposes specified on the product label is permitted. Label claims, directions for use and warnings are examined closely at the time of initial registration and at regular renewals afterwards. Consequently, it can be considered that use according to registered label directions will be safe and effective. The *Act* requires that pesticides be used only according to registered label directions for use or according to other directions that have been specially approved. **The onus is on the user to comply with this requirement.**

Pure Food Act 1908 (as amended) Under this legislation, maximum levels are specified for residues of pesticides on marketed foodstuffs. Specification of these levels is guided by the recommendations of National Health and Medical Research Council.

Poisons Act 1966 This legislation is concerned particularly with poisoning hazards associated with sale and storage of packaged pesticide and other possibly poisonous products. The minimum size of the container may be specified, thus determining whether the product will be used only in agriculture or in home and garden situations also. The product must be labelled to warn of the hazardous nature of the contents and advise on first-aid treatment.

Public Health Act 1902 Requirements under this legislation concern, amongst many other things, the safe use of certain pesticides and certain fumigants. If a person employs or supervises another who handles one of the specified pesticides, both are bound by the requirements, which apply to: condition of equipment used, provision and decontamination of protective clothing and equipment, instruction by employers, precautions for personal safety, personal washing amenities, illumination of working areas, restrictions relating to aerial spraying, labelling of containers, general safety precautions with containers, storage of pesticides, treatment of spillages, notification of accidents, disposal of containers, and notification of suspected poisonings.

Insecticides used in fruit and vegetable growing, and specified in regard to the requirements of the *Act*, include:

aminocarb
azinphos-ethyl
azinphos-methyl
carbophenothion
chlordane
chlorfenvinphos
demeton-S-methyl
dieldrin
endosulfan
endrin
ethion
fensulfothion
heptachlor
leptophos
methamidophos
methidathion
methomyl
mevinphos
monocrotophos
omethoate
parathion
parathion methyl
phosphamidon
promecarb

The fumigants, hydrogen cyanide, methyl bromide, ethylene dibromide, ethylene oxide and chlorpicrin may be used only by licensed operators, except that exemption may be granted in some circumstances in agriculture and horticulture.

References

Anderson, L. D., Atkins, E. L., Jr., Nakakihara, H. and Greywood, E. A. (1971). *Toxicity of Pesticides and Other Agricultural Chemicals to Honey Bees. Field study.* University of California Agricultural Extension Bulletin AXT-251.

Anon (1976). *Poisoning by Pesticides.* Division of Occupational Health & Radiation Control, Health Commission of New South Wales. 55pp.

Johansen, C. (1969). *The Bee Poisoning Hazard from Pesticides.* Washington Agricultural Experiment Station Bulletin 709.

Martin, H. ed. (1969). *Insecticide and Fungicide Handbook for Crop Protection.* Issued by the British Crop Protection Council. Blackwell Scientific Publications, Oxford and Edinburgh. 387pp.

Ware, G. W. (1978). *The Pesticide Book.* W. H. Freeman and Company, San Francisco. 197pp.

CITRUS

Introduction

Citrus districts of New South Wales

Citrus fruit trees are classified as sub-tropical, but they are highly adaptable providing they have sufficient soil moisture and the temperature does not fall too low. They are tolerant of both humid and arid conditions but are intolerant of high winds and long, frosty winters. Given adequate water, citrus fruit trees can be grown commercially almost anywhere in New South Wales except on the tablelands. There are, however, marked differences between the pests of the relatively humid coastal region and the drier inland areas.

Coastal citrus districts

These districts lie within about 50 kilometres of the coast. The most important areas are Gosford–Wyong, Kurrajong–Windsor, and Hawkesbury and Hills districts, with smaller areas near Camden, in the Hunter Valley and on the lower North Coast. The topography varies between country up to 300 metres above sea level at Mangrove Mountain and Kurrajong and areas close to sea level on the lower Hawkesbury and at Gosford.

The producing areas are scattered. Winters are mild and largely frost-free; rainfall is usually about 900 millimetres per year and fairly evenly distributed throughout the year except for a tendency towards dry months in the spring. Supplementary irrigation is available in many orchards.

Most Australian lemons are grown in the higher parts of this region, but the greater part of the citrus crop consists of Valencia and Washington navel oranges. Mandarins are grown fairly extensively in the Hawkesbury and Hills districts.

There are more than 50 citrus pests in the coastal districts but few of these require regular treatment. The pest complex may vary from district to district, from orchard to orchard, and sometimes even between different parts of the same grove. White wax scale has been the most widespread pest requiring regular control measures, but its importance diminished during the 1970s.

Control operations against pest insects and mites are often influenced by the requirements for fungus disease control. Black spot, melanose and lemon scab occur throughout the area and require regular treatments which may coincide with the timing of applications for pest control, and some fungicides are incompatible with some insecticides. Further, fungicide use may strongly influence infestation levels by some pests.

Citrus orchard, Gosford district.

Control practices against pests in the coastal region depend largely on petroleum oil, organophosphorus and carbamate compounds and sulphur – all applied as high-volume sprays.

Inland citrus districts

These districts lie to the west of the Great Dividing Range and each is associated with one of the western rivers. They have annual rainfalls of less than 460 millimetres, high summer temperature with low humidity and moderate winter temperature with some frosts. All citrus is grown with some irrigation in spring, summer and autumn. Tree growth is more dense than in the coastal region, and the trees tend to grow larger and become heavier croppers.

Citrus orchards, Murrumbidgee Irrigation Area.

The principal inland districts for citrus are the Murrumbidgee Irrigation Area, Upper, Mid- and Lower Murray River irrigation districts and smaller areas at Narromine and Bourke. Throughout these areas California red scale is the most serious pest and control measures are frequently an annual requirement, although the intensity of infestation varies from year to year.

In the absence of important fungus diseases (except for some septoria spot in occasional seasons), the fruit is generally less surface blemished than that on the coast. Most of the inland citrus plantings are in fairly large blocks on flat or gently undulating land. Dust accumulation on the trees in summer and autumn is often fairly heavy. Nutritional sprays, such as for the correction of zinc deficiency, are required from time to time. They are applied in early spring and do not coincide with pest control spraying, which is confined mainly to the summer.

Pest control operations depend mainly on high-volume application of petroleum oil sprays in summer against California red scale, with some use also of organophosphorus insecticides. However, there is increasing dependence on biological control of California red scale by parasites.

Development and growth of the citrus tree

All commercial varieties of citrus are evergreen. Although growth rate and root development slow down during winter, the trees have no true dormant period. New shoot and blossom development begins in July–August. The full development of spring growth shoots and of main-crop blossoms occurs in September and October. Petal-fall and fruit setting take place in October–November. There is heavy shedding of buds, blossoms and later of young fruits so that usually only a very small percentage of the original blossoms will eventually produce fruit. The fruit that will mature as the main crop is generally well set by February when it is about the size of a walnut or a golf ball. There is a second period of relatively vigorous foliage growth during January and February, but, except on lemon trees, blossoms are not normally produced at that time. Shoot growth is either static or at a low level in winter.

Fruit begins to colour in late April and May and develops full colour during winter. Washington navels, main-crop lemons, and most mandarins attain full maturity during winter. Valencias mature in the spring, but can hang on the trees right through the summer and into the autumn while the next season's crop is developing. It is common for the harvest of main-crop Valencias to be delayed in this way. Grapefruit follows a pattern of development similar to Valencias.

In the commercial production of oranges, mandarins and grapefruit the object is to have large crops of unblemished main-crop fruit of good colour and suitable size and juice content.

The aims in the commercial production of lemons are somewhat different. In addition to the main-crop fruit, which is largely for factory processing, an intermediate crop is developed from blossoms produced during January to April, and this is marketed at a high price during the following summer. Thus it is normal, and desirable, for lemons to carry fruit in various stages of maturity throughout the year.

Pest control operations against the main citrus pest, California red scale, aim to prevent the infestation of fruit early enough in summer to avoid blemishing of the rind and to allow the fruit to throw off any dead scales by further expansion before harvest. Winter treatment of citrus trees for red scale control is seldom practised as investigations have shown it to be ineffective. Strong spray mixtures, such as those used on dormant deciduous trees, are not applied to citrus, except in the control of white louse scale. To control this pest, strong lime-sulphur is applied in mid-winter, the safest time, although even then there is some risk of fruit- and leaf-fall.

Factors influencing the importance of insect and allied pests of citrus

The citrus tree provides a stable shelter for many insects because it is an evergreen. Pest populations may wax and wane in response to many factors.

Some of these factors are examined in further detail below.

Climate

In New South Wales the coastal districts differ from the inland citrus areas in having higher rainfall more evenly distributed over the year, higher atmospheric humidity and less extreme winter and summer temperatures. Most coastal district orchards are better protected from winds than inland orchards, and the coastal winds are less dry and dusty. Fungal diseases of citrus, such as black spot, melanose and lemon scab, are persistent problems in coastal areas, and mineral deficiencies of the soil, especially of copper and magnesium, are common.

The inland climate is drier, and the scanty rainfall in the southern areas is concentrated in the winter. Summer temperatures are higher than on the coast with lower atmospheric humidity, while winters are colder with light to moderate frosts. Winds are often strong, dry and dust-laden. The inland areas are almost free from fungus diseases of citrus, and the most common soil deficiency is of zinc.

Under the more benign conditions of the coastal region, white louse scale is ubiquitous, so also is white wax scale. Purple scale occurs there, mainly in areas close to the sea. Some of the insect pests of citrus in coastal districts are readily distressed or killed by high temperatures. This has been observed frequently, for example, in white wax scale and bronze orange bug infestations.

The inland areas are well suited to the development of California red scale, which is favoured by hot dry summers, high light intensity, heavy dust deposits on the trees and the long period over which mature Valencia fruits may remain on the trees. Under these conditions red scale is a pest of older rather than younger trees; the comparative lack of shade on young trees allows heat wave conditions to kill many scales.

The climate of the southern inland areas is unsuitable for some of the coastal pests, such as white and pink wax scale, purple scale, white louse scale, rust mites, spined citrus bug and bronze orange bug. However, the northern inland districts that receive summer rainfall are sometimes suitable for the development of certain coastal pests, notably white wax scale, rust mites and bronze orange bug; spined citrus bug is consistently important there.

The winter cold in citrus areas in New South Wales does not appear to cause significant mortality in citrus pests though their rates of development are reduced.

Topography

Differences in topography have some interesting effects. Lemons, usually grown on high ground, can escape serious damage from purple scale which develops best on trees close to

watercourses and does not thrive in exposed situations. California red scale tends to be associated particularly with lemons in coastal districts where it is favoured by the exposed situation. Brown citrus rust mite develops more successfully when protected from the wind, and so causes more fruit-blemishing on trees protected by buildings or windbreaks. Snails are most troublesome in low-lying orchards.

Citrus varieties

Striking differences are seen in the relative susceptibility of different citrus varieties to attack by various pests, although the main citrus pests will attack all varieties.

Pink wax scale strongly prefers mandarins, and attacks grapefruit more readily than oranges or lemons. In an arboretum of mixed citrus varieties, hybrids containing mandarin strain may be identifiable by their pink wax scale infestation. Citrus bud mite is primarily a pest of lemon and navel orange, so that navel or lemon strain in hybrids can often be identified by bud mite attack. The spined citrus bug most commonly infests lemons; limes, mandarins and kumquats. Citrus gall wasp shows a strong preference for rough lemon. For the armoured scales, differences in susceptibility of different varieties are usually small, and are probably the result of differences in canopy density and shade in the trees.

Age of trees

The age of a tree can have an important influence on the extent of its insect pest population. This is partly due to the amount of protection afforded by the canopy to both pests and natural enemies, and partly due to the natural reduction of vigour with advancing age. Insect pest problems during the early life of a tree may almost disappear as the tree ages, and be replaced by other pest problems.

Alternative hosts

The proximity of alternative host plants can affect population levels of some pests in citrus orchards. White wax scale, pink wax scale, black scale and Queensland fruit fly may readily re-infest citrus trees which have been recently and successfully treated.

Proximity to bushland

Sometimes the proximity of citrus orchards to bushland may cause special problems. An ant which nests in fallen bush trees may cause some harm by nibbling the margins of young citrus leaves. Termites occasionally invade new orchards through underground galleries from bushland; these attacks are usually limited to outer rows. Root, trunk and branch borers migrating from native trees, such as wattles, may be troublesome, but the health of the citrus trees is important in determining their susceptibility to damage.

Uses of insecticides on citrus

Insecticides used for control of pests on citrus, of which scale insects are by far the most important, must be safe to apply to actively growing trees, usually in warm weather, as high-volume drenching sprays. They should preferably be compatible with other pesticides, especially with copper and dithiocarbamate fungicides.

Suitable insecticides should have as little ill effect as possible on non-target biological control agents – the natural enemies of the pest species. The evergreen citrus tree supports a complex community of insects and unfavourable disturbance of this may lead to a serious pest problem. This was readily seen in experiments on spraying coastal citrus trees with DDT. Severe scale and mite pest infestation usually followed.

Citrus trees close to bushland.

A wide range of insecticides has been applied in research and commercial practice against pests of citrus, but the number of materials in use now is rather small.

Spraying with petroleum oil emulsion has long been the mainstay of citrus pest control and oil continues to be the principal pest control material used on citrus. Hydrocyanic acid gas fumigation was widely used against red scale in inland districts for many years and was extremely effective, but fell into disuse as orchard management and other practices and equipment and labour costs changed. Sulphur, particularly as lime-sulphur, has had long use against several pests in coastal districts. Alkaline sprays containing soda in various forms were used for many years, mainly against scales, before being replaced by better materials.

Modern insecticides appeared from the late 1940s onwards, and have been tested extensively. Chlorinated hydrocarbon and cyclodiene insecticides have little use in pest control for citrus. Some organophosphorus compounds as sprays are very useful against scales, but usually they have been employed most effectively in combination with petroleum oil sprays (Hely and Gellatley, 1960). Carbamates, such as carbaryl, can be used very effectively against soft scales, but caution is needed to avoid upsurges of non-target pests.

Petroleum oil

The development of effective petroleum oil sprays that are relatively free of plant damage risk to citrus, and the specification of suitable grades of oil, has been carried out mainly in the United States of America.

Emulsions of kerosine and soap in water were the earliest oil sprays. Later, emulsions of poorly-refined lubricating oils, generally known as 'red oils' were used. Fruit or tree injury was common and could be very severe. In the 1920s major advances were made in the development of safe and satisfactory petroleum oil emulsion sprays for citrus (Ebeling, 1959). It was found that unsaturated hydrocarbon constituents of the oil were a common

cause of plant injury, and they could be removed in the refining process. Better emulsifying agents were used, and 'quick breaking' emulsions were produced from which the oil was deposited as a continuous film on the plant. The spraying oil concentrate was an emulsion with a thick mayonnaise-like consistency, which gave it the name 'mayonnaise emulsion'.

Mayonnaise emulsion concentrates are usually about 85 per cent petroleum oil emulsified in about 15 per cent of water, by means of casein and ammonia. They are often called 'white oils' but this name is also used for the more recently developed miscible or emulsive formulations of petroleum oil for spraying citrus. These are oils with dissolved emulsifier (less than 3 per cent of the volume); they form emulsions when added to the water in the spray tank. The base oil is often the same as that used to make mayonnaise emulsion. The miscible or emulsive formulations are more stable during storage than mayonnaise emulsions and mix more readily with water in the spray vat. Mayonnaise emulsions may deteriorate in the container, and the oil separate out, when stored in hot situations; tree injury can occur if it is then used for spraying.

The nature of the base oil, as distinct from the emulsified or emulsive concentrate, has been described by Trammel and Simanton (1966). When crude petroleum oil is distilled, base oils potentially suitable for spraying come off in the same distillation temperature range as light lubricating oils. The base oils will be predominantly hydrocarbons of paraffinic (saturated chain) or naphthenic (saturated ring) structure, mainly according to the nature of the crude oil. Paraffinic oils usually contain 60 to 75 per cent paraffinic hydrocarbons, while oils with 45 per cent or more of saturated ring compounds are considered to be naphthenic. Highly paraffinic oils are more efficient insecticides than naphthenics (Riehl and Carman, 1953).

In the various citrus areas of the world, different spraying oils may be used. The choice is dependent on the type of oil stocks available in the region, and their suitability is influenced by the climate of the area, the time of year for application and the citrus varieties to be sprayed.

SPRAY OIL SPECIFICATIONS Chemical and physical specifications of a spray oil base can indicate its suitability. The most useful criteria are distillation range and unsulphonated residue. Distillation range of an oil refers to the temperature range over which its constituents will boil. It indicates the 'heaviness' and hence the volatility of the oil. As an insecticide, the longer the oil remains on the tree the better, but the quicker the oil evaporates the better it is for the tree. Specification of the temperatures at which 10 per cent, 50 per cent and 90 per cent of the oil distil indicates its homogeneity. Viscosity has been used to indicate the 'heaviness' of an oil but it can be misleading as viscosity is also dependent on paraffinicity (that is, the proportion of paraffinic to naphthenic and aromatic compounds).

Unsulphonated residue (U.R.) gives the content of saturated hydrocarbons. This is relevant to one source of risk of plant damage, for unsaturated hydrocarbons, which are chemically less stable, may cause plant injury. When the expression was first used a U.R. rating of at least 85 per cent was recommended. Later, improved techniques of refining spray oils made U.R. ratings of 92 per cent, and higher, feasible.

In California, spraying oils have been classified since 1932 in grades according to 'heaviness'. Specifications for the 'California grades' of spray oil are given in terms of U.R. and of percentage distilled at 636°F at atmospheric pressure. They have been listed by Riehl (1969) along with observed average distillation range temperatures and viscosity values, as shown below (Table 4).

Ebeling (1959) noted that the citrus varieties have varying tolerances to oil, for example, lemon and grapefruit are more tolerant than orange. He stated that the aim of oil-spraying citrus in California was to apply the heaviest oil which could be used safely on a given variety in a given region and season of the year. However, recommendation of the California grades of oils in recent years by the University of California Division of Agricultural Sciences (Anon, 1980) has been confined to light-medium and medium grades, applied at 1.6 to 1.8 per cent oil concentration.

NARROW-RANGE SPRAY OILS Riehl (1969), in tracing the history of spraying oils, pointed out that the difficulty in selecting a suitable grade of oil for spraying citrus was the large distillation range of the California grades and the overlap of ranges of adjacent grades. The development of narrow-range spray oils during the 1960s tended to overcome this problem. An oil of this type has a narrow distillation range which indicates uniformity of its hydrocarbon components. Specifications of the main narrow-range oil type recommended in California (Anon, 1980), for use at 1.2 to 1.4 per cent oil concentration, are:

Distillation at 10 mm Hg (A.S.T.M. Method D-1160)	
50% point	415°F
within limits	412° to 418°F
10% to 90% range	maximum 60°F
Percentage carbon atoms in paraffinic structure (RI-KVGC analysis)	minimum 60%
Percentage unsulphonated residue (A.S.T.M. Method D-483)	minimum 92%
Pour-point* (A.S.T.M. Method D-97)	maximum +20°F

* The pour-point property indicates the extent to which the oil has been de-waxed.

Table 4 Selected properties of California grades of foliage spray oils

Grade	*Specified*		*Observed average*		
	Unsulphonated residue (U.R.) (per cent)	Per cent distilled at 636°F at atmospheric pressure	Temperature at which indicated per cent distilled at atmospheric pressure 5%	90%	Viscosity (seconds Saybolt Universal, at 100°F)
Light	90	64–79	555°F	685°F	55–65
Light-medium	92	52–61	575°F	700°F	60–75
Medium	92	40–49	585°F	715°F	70–85
Heavy-medium	92	28–37	595°F	715°F	80–95
Heavy	92	10–25	610°F	730°F	90–105

Effects of oil sprays on citrus trees Petroleum oils are important sprays for pest control on citrus. They are safe to handle, have little effect on natural enemy insects, and may be applied in combination with many insecticides and fungicides.

Oil sprays are applied as emulsions. They break on striking the trees to leave oil adhering whilst water and emulsifier drain away. This primary deposit of oil results from the preferential affinity of plant cuticle for oil; the effect is more evident with lemons than with oranges. Droplets of spray fluid which remain on the tree also carry some oil; the water evaporates and this oil is left as a secondary deposit.

Penetration into the plant occurs through the stomata. It is rapid, and is visible as dark oil-soaked blotches on young green fruits, undersides of leaves and green twigs. In the leaves, the oil migrates to the midrib areas and the leaf margins, and the dark discoloration may persist for months.

The oil affects fruit and tree physiology, for example, vigorous shoot growth in January and February is often observed on trees sprayed with oil in December. The spray also affects transpiration and sprayed trees have been known to withstand very dry weather better than unsprayed trees. However, spraying drought-affected trees risks leaf- or fruit-fall so it is not recommended.

In normal use oil sprays have few deleterious effects, but under some circumstances they can injure the tree by causing either acute or chronic damage. Acute damage results in leaf-burn, fruit-fall and leaf-fall, and may involve immature as well as mature leaves and fruit. The damage may be unimportant, such as when the loss is only of old leaves or of immature green fruits which are expected to be shed normally as the season advances. Burning is most likely to occur after spraying in very hot (over 35°C) still conditions. This is probably from the effects of the sun through spray fluid drying slowly on the trees, and is most marked on the northern and western sides.

These acutely damaging effects can occur with a normally satisfactory oil spray if it is used in very hot still weather, or on trees in poor health or recently sprayed with sulphur. Of course, damage has also followed the use of unsuitable products such as sprays formulated from base oils that have low U.R. figures or are too 'heavy', or oil emulsions that have separated out during storage or in the spray vat to release free oil.

Injury from oils that have separated out is most often seen on trees which were sprayed when the vat was nearly empty, as they will have received some of the free oil. Drums of mayonnaise emulsion that have been stored for long periods, or in hot conditions, should be checked for free oil before use. Small amounts of free oil can be re-mixed by shaking the drum.

Chronic harmful effects follow too much use of oil spray – such as more than one application per season at 2 per cent concentration – or spraying in late autumn. The effects can be:

- ☐ reduction in blossoming in the following spring. This may restrict fruit set seriously if the reduction impairs a normally light blossoming, such as may follow a heavy crop year. The reduced blossoming may be beneficial if it occurs in a spring when the production of blossom might otherwise be excessive.
- ☐ production of rough-skinned, puffy, poorly-coloured fruit that is sometimes over-large and lacks flavour.
- ☐ die-back of twigs over a long period.
- ☐ excessive blemishing of fruit by windrubs and scratches, apparently brought about by softening of skin of the immature fruits.

Oil spray in summer, in inland orchards, has sometimes affected some of the developing fruit on Valencia trees. The fruit was dwarfed, bronzy-coloured, dry and dark-seeded, and fell prematurely.

Navel oranges sprayed in summer can suffer another form of injury if the following winter is wet. After prolonged periods of rainy weather, sunken brown depressions, called 'water spots', develop on the mature oranges around the navel or on the shoulders where the rind has been softened by oil and water can penetrate.

Petroleum oil sprays are generally capable of combining satisfactorily with most insecticides and fungicides used on citrus, and often enhance their effectiveness. They are commonly used as spreaders and Kiely (1963) has drawn attention to the suitability of mayonnaise emulsion white oil, but not miscible or emulsive formulation, for use as a spreader with Bordeaux mixture. Mixtures of petroleum oil with organophosphorus insecticides make satisfactory sprays. Oil may also be combined with carbaryl, Bordeaux mixture at strengths up to 250 grams bluestone–250 grams lime–100 litres water, other copper fungicides, zineb, mezineb, soda ash or washing soda.

Petroleum oil should not be combined with either resin soda or sulphur compounds. It should not be used until about three weeks after spraying with sulphur, as severe injury may occur, especially if the oil is applied in hot weather.

Effects of oil sprays on insects Petroleum oil sprays are mildly toxic to many insects but are especially effective against scale insects and mites. Most oil spraying of citrus is to control scales, particularly California red scale. A great deal of study has been devoted to the mechanisms of toxicity of oils to this scale insect.

The respiratory system of the scale insect consists of an arrangement of branching tubes, called 'tracheae', that are further divided into finer tubes or tracheoles which penetrate every part of the body. The insect's body cells receive oxygen and give off waste gases by diffusion through the walls of the tracheoles. The tracheae open to the exterior through spiracles around the margins of the body. When the scale is sprayed, it is covered by an oil film, some of which penetrates the tracheae by capillary action through the spiracles. The insect will then die from suffocation over a period of up to ten days. Very light oils, such as kerosine, penetrate the tracheae rapidly, but are not very effective as they can also be expelled quickly. Oil can also penetrate the dorsal scale cover with a delayed lethal effect (Smith, 1932).

Ebeling (1936) showed that there is a very significant reduction in the percentage of California red scale crawler scales able to settle on the leaves for at least a month after spraying, and that many of those which do settle die afterwards; the immature stages of the red scale are more easily killed by oil than the adults, probably because they are not as thoroughly sealed to the plant surface and their spiracles are closer to the margins of their bodies; adult scales which live for two weeks after spraying will produce many dead embryos or dying crawlers.

Oil sprays are absorbed at different rates by different tree surfaces and scale kill is least where absorption is rapid. The bark of the trunk and main branches absorbs oil readily and reduces the amount available to kill scales.

Hydrocyanic acid gas (HCN)

Fumigation with HCN gas for the control of scale insects was first developed in California (Morse, 1887; Coquillet, 1890). The treatment consisted of covering the tree with a tent, releasing the

gas inside, and leaving the cover in place for a suitable time – about 40 minutes. It was a highly effective method and was used in New South Wales for over 50 years.

At first the HCN was generated from potassium or sodium cyanide, with sulphuric acid. This method was replaced by use of calcium cyanide powder, which gave off the gas without the acid. Calcium cyanide was used also as briquettes ground to a powder in an applicator that blew the powder under the trees. Liquid HCN absorbed on diatomaceous earth was used for a time and finally liquid HCN, stored in steel cylinders, was used.

HCN fumigation of citrus was introduced to Australia in the late 1890s (Allen, 1901). Much study was devoted to the method, particularly in the United States, and also in Australia, and an extensive series of papers was published, for example, by Woglum (1923), Arthur and Harrison (1926), Benton (1927), Quayle (1928), Woodhill (1930), Hely (1933, 1940), Anon (1951). It was found that the treatment should be done at night because summer daylight added to the risk of tree burn. The night temperature and humidity and usual absence of wind were also more favourable than daytime conditions. Trees could be damaged by the fumigation, especially if they were growing in sandy soil or were affected by root rot. Fumigation following, even after an interval of months, spraying with copper fungicides or manganese nutritional spray caused severe injury.

Fumigation was never very suitable in New South Wales coastal districts, but was used for a long time in inland areas.

From the 1950s onwards fumigation declined, and in the 1970s disappeared, due to improved efficiency and economy of spray equipment and insecticides, high cost of fumigation equipment and the shortage of expert labour and, finally, shortage of cyanide supplies.

Sulphur

The use of sulphur compounds for spraying citrus in New South Wales can be traced back into the last century. Now sulphur is mainly used either as wettable powder sulphur spray or as lime-sulphur spray.

Wettable powder formulations of sulphur are used as sprays against mites and white louse scale. Their usefulness is limited by the danger of burning foliage and fruits in very hot weather at the time of spraying or soon after. If applied annually in spring, they suppress white louse scale infestation levels and avoid the tree injury risk attendant on the use of the more effective lime-sulphur.

In spring, wettable sulphur can be applied with Bordeaux mixture used for disease control, and has been used with spreader strength of petroleum oil without significant tree injury. Later in the year, sulphur and petroleum oil sprays must not be mixed, nor should petroleum oil be used within about three weeks of spraying with sulphur.

Lime-sulphur is used in coastal citrus orchards to control white louse scale. It is applied in strong concentration to give an effect lasting several seasons, and is used in winter to minimize spray injury risk.

For many years lime-sulphur was home-made by boiling quicklime and sulphur together, but it was difficult to make and variable in composition. In the early 1930s it was found that the active insecticidal and fungicidal principle in lime-sulphur depended on the total soluble sulphur compounds, especially the polysulphides. When lime-sulphur is manufactured under standardized conditions, a product having a specified polysulphide content can be assured. Commercial lime-sulphurs usually contain 20 per cent polysulphide sulphur.

Sulphur applications do not control white louse scale by direct mortality. The effects, which are most pronounced with lime-sulphur, are as follows (Hely, 1944):

- ☐ adult male scales are prevented from emerging.
- ☐ scales which are immature at the time of spraying can not complete their covering – the body continues to develop beyond the abbreviated cover and, though the insects may live for a long time, they fail to reproduce.
- ☐ larval scales fail to emerge from beneath the parent, but accumulate under the scale cover and die.

Thus, although the scale population present at spraying persists for a considerable time after treatment, the individuals fail to reproduce and gradually the majority die. The final result is a declining population of mature scales with little or no replacement by fresh crawlers.

Resin soda, soap and soda

Resin soda spray has been used against scales and some other insects, including bronze orange bug (Summerville, 1934). It was made by boiling resin with caustic soda and either fish oil, or whale oil or soft soap. A formula used in Queensland was published in 1951 (Anon).

Resin soda gave erratic results against scale insects, particularly against armoured scales. Its insecticidal action is not understood, but an experiment at Gosford (Hely, unpublished data) suggested the involvement of dew condensation on the trees and perhaps the liberation of fatty acids. Siegler and Popenoe (1925) suggested that the toxicity of soaps as contact insecticides may be due to fatty acids being released by dissociation in aqueous solution. The rapid and violent mortality of second-instar bronze orange bugs sprayed with soft soap (Hely, 1944) suggests the action of a dynamically toxic mechanism.

Soda spray (washing soda or soda ash, with added soap or oil) may be used in late summer against young white or pink wax scales which have formed a small protective coating of wax. Soda can cause leaf-fall and fruit damage, especially in hot weather or on trees sprayed with Bordeaux mixture. The fruit damage is commonly a diffuse speckled marking which is apparent when the fruit colours.

Soda ash is preferred for its stable composition. Sodium metasilicate can also be used against wax scales, and it is associated with similar risks of tree damage.

Organophosphorus insecticides

Organophosphorus (OP) sprays can give better kills of scale insects, especially armoured scales, than petroleum oil spray alone. A wide range of OP insecticides in various formulations has been tested on citrus in New South Wales, chiefly against California red scale (inland) and white wax scale (coastal districts) (Hely and Gellatley, 1960). Combinations of some of these insecticides with half-strength petroleum oil have proved to be effective scale killers. Dimethoate, maldison and ethion, which have relatively low to moderate toxicities to the operators, have been used most widely in this way. Ethion is available in a formulation with petroleum oil. More recently, methidathion (an OP with higher toxicity to the user) has proved to be very effective even when used without oil.

Each of the OP insecticides is individual in the range of insects controlled, toxicity to the user, phytotoxicity, and compatibility with other spray materials. There is a general tendency to

incompatibility with alkaline materials such as Bordeaux mixture. It is these individual characteristics which will determine the choice of an OP for a specific pest control purpose.

While parathion was the first OP to be used on citrus for scale control, it has not been used extensively in New South Wales. It is used widely overseas but its high toxicity to man and tendency to stimulate soft brown scale infestations have influenced its use in Australia.

The action of OP compounds against scale insects is only imperfectly understood. Some have residual action against young scales. Rain after spraying interferes to some extent, but using the insecticide in combination with petroleum oil reduces this. Some OP insecticides are more effective against scale on specific types of tree tissue. Georgala (1963) stated that parathion was most effective against red scale infesting the wood and dimethoate most effective against red scale on fruit.

It is generally preferable to use OP insecticides on citrus as wettable powders. Although there are exceptions, emulsion formulations tend to blemish young green citrus fruits. The blemish is usually a circular mark on the fruit at the point where drying of the spray was slowest.

Organophosphorus insecticides are used on citrus also against aphids and plant bugs. Materials with some persistence as systemics in the plant sap, such as demeton-S-methyl and dimethoate, are chosen for use against aphids. The action against bugs is by contact with the spray, so materials such as maldison and dimethoate are suitable. Dimethoate can be phytotoxic to kumquat, Meyer lemon and Seville orange.

Some organophosphorus emulsion sprays have blemished citrus fruits.

Carbamate insecticides

Carbaryl and promecarb are highly effective against white wax scale and black scale, and they are usually applied with half-strength petroleum oil. Increases in purple scale infestation have been seen following spraying with carbaryl.

Carbaryl has other uses in citrus spraying as a control measure against leaf-eating insects such as Fuller's rose weevil adults. The effectiveness of carbaryl is reduced if it is applied with Bordeaux mixture.

Chlorinated hydrocarbon insecticides

Chlorinated hydrocarbon insecticides have only limited usefulness on citrus. Spraying with DDT causes great increases in scale and mite infestations. Lindane is effective against aphids and bugs, and is compatible with Bordeaux mixture, but may taint ripening fruits.

The cyclodienes, dieldrin and chlordane, have been used against pests of citrus such as weevils and borers. In view of the desirable trend towards minimizing cyclodienes in the environment, the recommended use of them on citrus is restricted to chlordane for ant control, applied under trees and to ants' nests.

Synthetic miticides

Synthetic chemical miticides have been used only occasionally on citrus in New South Wales. Dicofol and tetradifon are the only synthetic miticides which have been used against the limited occurrences, to date, of citrus red mite.

Zineb, a dithiocarbamate fungicide, is highly effective against rust mites, but is not useful against other mites affecting citrus.

Resistance of citrus pests to insecticides

Attention was first drawn to the resistance of an insect to an insecticide when Melander (1914) reported that San José scale had become difficult to kill with lime-sulphur. Then Quayle (1916) reported the increased tolerance to HCN gas of California red scale in California. As time passed, resistant strains of red scale were found in California over a wide area, but the degree of resistance did not appear to increase. Ebeling (1950) reports that, in California, resistance to HCN was noted in black scale in 1915, and in citricola scale in 1925.

In other citrus-growing areas of the world, spider mites, such as citrus red mite, show resistance to organophosphorus compounds, and citrus rust mite resistance to zineb is recorded in Florida, Israel and Cyprus (Jeppson, 1969).

Recently, resistance of California red scale to organophosphorus insecticide sprays has occurred as a serious problem in South Africa (Carman, 1978).

In New South Wales no authenticated case of the resistance of any citrus pest to any insecticide has been reported.

Spray application

The technique of spraying needs to be matched to the pest control purpose sought. Fairly thorough coverage of the tree is required when spraying against most pests of citrus, in order to contact them with the spray. Against the principal pest in inland districts, California red scale, spray coverage must be very thorough.

No matter how effective the spray material may be, the controlling factor in achieving satisfactory results is thoroughness of coverage. Any spraying operation against scales must aim to contact each individual insect. The treatment can have some effectiveness against scale larvae which emerge from under the adult females over several days after spraying, but this only contributes to the overall control effect. To date, no systemic insecticide spray has been found which can control citrus scales by long-term systemic action.

Complete coverage spraying of citrus is not easy. Most scale control spraying is done while the trees have dense foliage and are carrying the immature crop, and Valencias may be carrying mature fruit also. Special attention is needed to spraying projecting shoot growth and the tops of the trees.

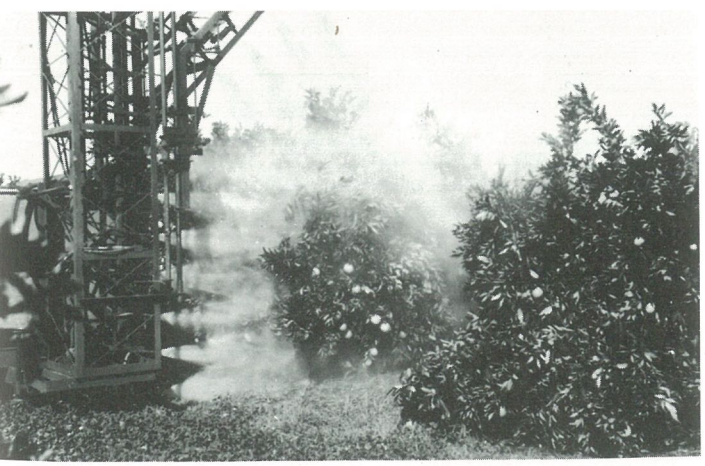
There is no precise answer to the question of how much spray should be applied per tree. As a rough guide, it may be assumed that trees about 3 metres high require about 50 litres of spray for thorough coverage. There will be considerable run-off from thoroughly sprayed trees. This must be accepted, but when oil

spray alone is being used much of the run-off will be water, as the oil will be deposited on the tree from the quick-breaking emulsion.

In high-volume spraying of citrus, the spray machine operates at high pressure – about 3500 kilopascals for Calfornia red scale control spraying – and this, combined with high-volume output allows rapid coverage of the tree. Spray pressure alone does not determine the degree of scale kill, so low-pressure spraying can be effective but will be slower in achieving adequate coverage.

Spraying with hand-held spray rods has now been replaced almost entirely, due to high costs of labour, by the use of automatic drive-past spray machines. There are many types which include high-volume, semi-concentrate, and concentrate sprayers, but high-volume machines have proved to be the most satisfactory for citrus orchard spraying so far. Of the automatic high-volume sprayers, large oscillating boom machines with vertical and overhead booms ejecting narrow cones of spray from rapidly-moving multiple nozzles approach as closely as possible the efficiency of good hand spraying.

Large oscillating boom sprayer.



Citrus tree being sprayed by a large oscillating boom.

Hand spraying citrus.

Citrus pests

An account is given on pages 23 to 83 of the pests of citrus listed below.

ARTHROPODA

INSECTA

LEPIDOPTERA

Large citrus butterfly	*Papilio aegeus aegeus* Donovan
Small citrus butterfly	*Papilio anactus* Macleay
Orange fruit borer	*Isotenes miserana* (Walker)
Light-brown apple moth	*Epiphyas postvittana* (Walker)
Leaf case moth	*Hyalarcta huebneri* (Westwood)
Lemon bud moth	*Prays parilis* Turner
Citrus leaf-miner	*Phyllocnistis citrella* Stainton
Budworms	*Heliothis* spp.
Fruit-sucking moths	Noctuidae

HYMENOPTERA

Citrus gall wasp	*Bruchophagus fellis* (Girault)
Paper nest wasps	*Polistes* spp.
Ants	Formicidae

DIPTERA

Queensland fruit fly	*Dacus tryoni* (Froggatt)
Island fruit fly	*Dirioxa pornia* (Walker)

COLEOPTERA

Fuller's rose weevil	*Asynonychus cervinus* (Boheman)
Elephant weevil	*Orthorhinus cylindrirostris* (Fabricius)
Dicky rice weevil	*Maleuterpes spinipes* Blackburn
Citrus leaf-eating weevil	*Eutinophaea bicristata* Lea
Fruit tree root weevil	*Leptopius squalidus* (Boheman)
White striped weevil	*Perperus lateralis* Boisduval
Apple weevil	*Otiorhynchus cribricollis* Gyllenhal
Pittosporum longicorn	*Strongylurus thoracicus* (Pascoe)
Fig longicorn	*Dihammus vastator* (Newman)
Citrus branch borer	*Uracanthus cryptophagus* Olliff
Citrus longicorn	*Skeletodes tetrops* Newman
Speckled longicorn	*Paradisterna plumifera* (Pascoe)
Monolepta beetle	*Monolepta australis* (Jacoby)
Pitted apple beetle	*Geloptera porosa* Lea

THYSANOPTERA

Greenhouse thrips	*Heliothrips haemorrhoidalis* (Bouche)
Citrus rust thrips	*Chaetanaphothrips orchidii* (Moulton)
Plague thrips	*Thrips imaginis* Bagnall
Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

California red scale	*Aonidiella aurantii* (Maskell)
Yellow scale	*Aonidiella citrina* (Coquillett)
Purple scale, mussel scale	*Lepidosaphes beckii* (Newman)
Glover's scale	*Insulaspis gloveri* (Packard)
White louse scale	*Unaspis citri* (Comstock)
Circular black scale	*Chrysomphalus aonidum* (Linnaeus)
White wax scale	*Gascardia destructor* (Newstead)
Pink wax scale	*Ceroplastes rubens* Maskell
Chinese wax scale	*Ceroplastes sinensis* Del Guercio
Black scale	*Saissetia oleae* (Olivier)
Soft brown scale	*Coccus hesperidum* Linnaeus
Citricola scale	*Coccus pseudomagnoliarum* (Kuwana)
Cottony cushion scale	*Icerya purchasi* Maskell
Long-tailed mealybug	*Pseudococcus longispinus* (Targioni-Tozzetti)
Citrus mealybug	*Planococcus citri* (Risso)
Citrophilous mealybug	*Pseudococcus calceolariae* (Maskell)
Australian citrus whitefly	*Orchamoplatus citri* (Takahashi)
Black citrus aphid	*Toxoptera aurantii* (Boyer de Fonscolombe)
Black citrus aphid	*Toxoptera citricidus* (Kirkaldy)
Spined citrus bug	*Biprorulus bibax* Breddin
Green vegetable bug	*Nezara viridula* (Linnaeus)
Bronze orange bug	*Musgraveia sulciventris* (Stål)
Crusader bug	*Mictis profana* Fabricius
Citrus blossom bug	*Austropeplus* sp.
Rutherglen bug	*Nysius vinitor* Bergroth
Green plant-hopper	*Siphanta acuta* (Walker)
Passionvine hopper	*Scolypopa australis* (Walker)
Leafhoppers	Cicadellidae

ORTHOPTERA

Inland katydid	*Caedicia simplex* (Walker)
Citrus katydid	*Caedicia strenua* (Walker)
Giant grasshopper	*Valanga irregularis* (Walker)
Spur-throated locust	*Austracris guttulosa* (Walker)
Australian plague locust	*Chortoicetes terminifera* (Walker)

ARACHNIDA

ACARINA

Citrus bud mite	*Eriophyes sheldoni* Ewing
Citrus rust mite	*Phyllocoptruta oleivora* (Ashmead)
Brown citrus rust mite	*Tegolophus australis* Keifer
Broad mite	*Polyphagotarsonemus latus* (Banks)
Citrus red mite	*Panonychus citri* (McGregor)
A flat mite	*Brevipalpus* sp.

ARANEIDA

Webbing spider — *Ixeuticus longinquus* L. Koch

MOLLUSCA

GASTROPODA — SIGMURETHRA

Common garden snail — *Helix aspersa* (Müller)

ARTHROPODA

INSECTA — LEPIDOPTERA

Large citrus butterfly *Papilio aegeus aegeus*
Small citrus butterfly *Papilio anactus*

Importance and Distribution The caterpillars of these native butterflies feed on new growth of citrus trees and can cause quite severe damage to young trees. They are found wherever citrus is grown in New South Wales, but the small citrus butterfly is the more abundant species in inland areas.

Conditions for Infestation An abundant growth of new foliage is required by these insects. They are found mainly on citrus growth-flush foliage in summer and autumn.

Plants attacked The caterpillars feed on cultivated citrus of all varieties. They also attack many plant species in the family Rutaceae (to which citrus belongs).

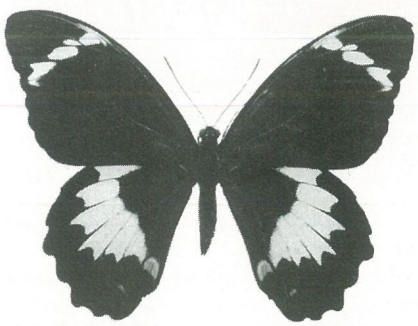
Description and Life History

LARGE CITRUS BUTTERFLY The female measures about 13 centimetres across the outspread forewings which are mainly brown to black with the outer parts white or grey. The hindwings are spectacularly marked with white, orange-red and blue. The male has wings which are mainly black with white markings. The full-fed caterpillar is 6.5 centimetres long and brown to olive green with three oblique brown bands edged with white on the sides. When disturbed, the caterpillar protrudes a red fleshy forked process from behind its head and emits a strong odour. The chrysalis, nearly 5 centimetres long, is attached to the food plant in an upright position by a silken pad and a thin silken girdle spun by the caterpillar. In late summer the pupal stage lasts for two or three weeks, but those which pupate later do not emerge as butterflies until the spring.

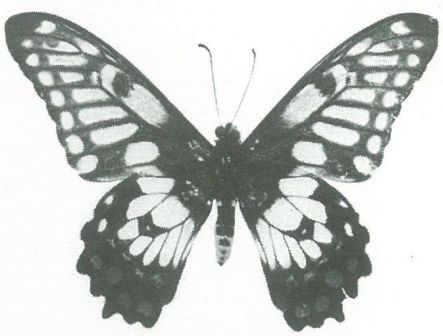
SMALL CITRUS BUTTERFLY This species resembles the large citrus butterfly, but measures only 7.5 centimetres across the outspread forewings. The colouring is similar in males and females. The forewings are black with grey and white markings and the hindwings have white, orange-red and blue markings. The full-fed caterpillar is about 4.5 centimetres long and has three rows of orange-yellow spots along its body. Like the larger species, the caterpillar protrudes a red, fleshy forked process and emits a strong odour when disturbed.

Caterpillar of the large citrus butterfly. (Length 6.5 cm when fully fed)

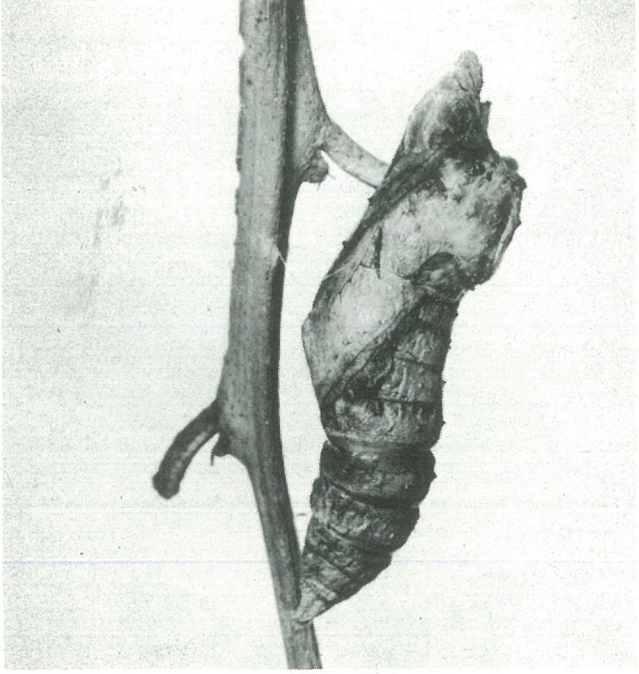
The large citrus butterfly – female. (Wingspan 13 cm)



The large citrus butterfly – male. (Wingspan 12 cm)



The small citrus butterfly. (Wingspan 7.5 cm)



Chrysalis of the small citrus butterfly. (Length 2.5 cm)

Caterpillar of the small citrus butterfly. (Length about 4.5 cm when fully fed) P.R.I., Dept of Ag. Vic.

The eggs of both citrus butterflies are almost spherical and about 2.5 millimetres in diameter.

The butterflies emerge in early spring from overwintering pupae, and lay their eggs singly on young citrus shoots. The eggs hatch in seven to ten days and the caterpillars feed on young leaves for four to six weeks. Two or three generations are produced in the year. They are most active in February and March.

Injury The caterpillars feed on young foliage, chewing out large areas from the leaf edge inwards. Severe attack can reduce shoots to bare twigs. This damage can be serious on young trees in the nursery and in newly planted orchard blocks, but is usually not very harmful to mature trees.

Dispersal The adults are strong fliers.

Control measures

NATURAL Small wasp parasites kill considerable numbers of larvae and pupae. Predacious bugs are known to attack the larvae.

APPLIED Spraying with carbaryl 0.1 per cent is suitable. Hand picking is often sufficient.

Orange fruit borer *Isotenes miserana*

Importance and Distribution This is a coastal species that occasionally causes important losses. The larvae bore into maturing and ripe fruit causing it to fall and decay; sometimes they destroy new young fruit in spring. Very young larvae may penetrate fruit just before harvest, and the injury will be undetected in packing but cause the fruit to decay during marketing.

Conditions for Infestation Most damage occurs in winter and early spring. Trees carrying good crops of clustered fruit, especially in sheltered situations and with abundant spider webbing, provide conditions most suitable for attack.

Plants attacked Orange fruit borer feeds on many plants including *Cupressus* windbreak trees. It is particularly attracted to the new growth of camphor laurel and to all varieties of citrus fruits, but feeding on citrus foliage is uncommon.

Description and Life History The adult moths are pale grey, speckled with small brown marks, bell-shaped when at rest and measure about 1.5 centimetres across the outspread wings. They fly with a fluttering action, mostly at night when the pale green eggs are laid in clusters where they overlap rather like fish scales.

The larvae are green at first, then cream with three red-brown longitudinal bands and a dark brown head capsule. They wriggle backwards vigorously when disturbed.

Egg masses are laid on leaves or fruit. The young larvae move to the calyx end of nearby fruit or to where the fruit contacts a leaf or another fruit. The larva bores through the rind and feeds on the white albedo, sometimes penetrating the flesh. Several feeding places may be used but it is rare for more than one caterpillar to damage one fruit. The full-fed larva pupates in either a dead rolled leaf, or a mass of flower debris, or webbed foliage. The pupal stage lasts for two to three weeks.

The time spent in the larval stage varies from one month to several months. The pupae are brown or green-brown, approximately 13 millimetres long and found on the foliage. Larvae hatched in autumn feed through the winter and produce moths in about August. There are several generations in a year but activity is least in summer. All stages can be found in winter.

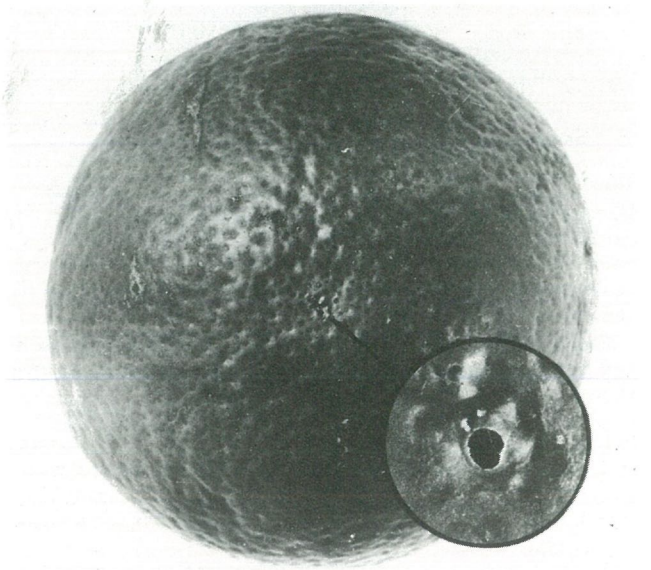
Injury Evidence of injury is most common in maturing or ripe fruits in autumn, winter and spring, when premature colour development indicates that the fruit has been attacked. Sometimes young fruits are attacked in spring, or in late summer. Second-crop fruits are subject to attack especially when the crop is heavy and clustered. On young green fruits the larvae make shallow pits in the rind and gum may form at the wound. Attack is most common amongst fruit in clusters, and where it is densely webbed by spiders. Maturing oranges, if attacked, will develop colour prematurely and fall. Examination usually reveals a small hole in the rind and, beneath it, a shallow excavation into the flesh. This is commonly at the point of contact with a leaf or another fruit. If no such damage is apparent, there will often be a pinhole in the calyx area. In navel oranges, the entry is frequently through the navel cavity. Intermediate-crop lemons are sometimes attacked heavily in winter.

Dispersal The moths fly weakly and their range is usually only from tree to tree.

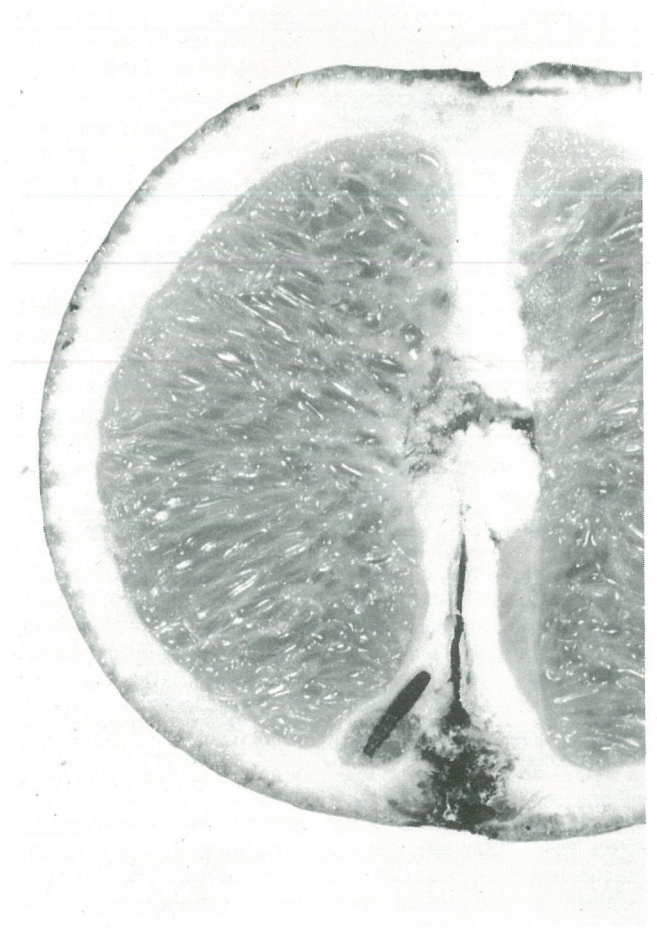
Control measures

NATURAL Little is known of natural enemies.

APPLIED Azinphos-methyl 0.05 per cent or carbaryl 0.1 per cent sprays, which control the related pest, light-brown apple moth, probably would be effective against orange fruit borer.



Orange fruit borer damage in side of fruit.



Orange fruit borer damage in navel, and larva.

Light-brown apple moth *Epiphyas postvittana*

Importance and Distribution This native insect is a more important pest of stone and pome fruits. The first record of it as a pest of citrus in New South Wales was by Froggatt (1899a), but it is not a major citrus pest. It causes damage mainly in inland areas.

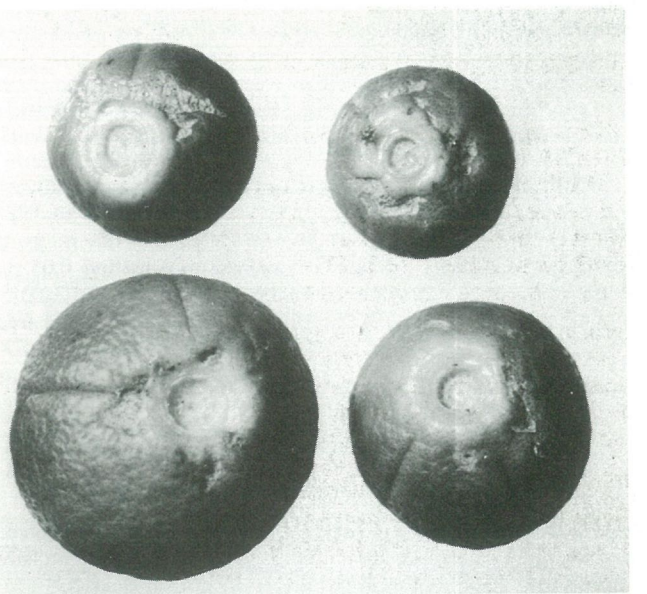
Conditions for Infestation Damage to citrus may be expected in seasons with mild moist weather in the cooler parts of the year. Activity decreases with the approach of summer.

Plants attacked The light-brown apple moth feeds on a wide range of plants, including nearly all fruit trees, many ornamentals, native trees such as wattles, clovers and weeds. Capeweed is an important host during winter.

Description and Life History The appearance of the various stages is described on page 96 under Apple Pests.

The egg masses, containing approximately 20 to 30 eggs, are laid on the surface of the plant. In spring the life of the larva is five to six weeks, but is less in warm conditions. Pupation takes place among flower debris or in rolled leaves; about two weeks are spent in the pupal stage. Moths emerging in summer live for about two weeks, but their life is likely to be longer under cooler conditions. During winter, the larvae are present on citrus, but large numbers of larvae may also be on capeweed in the orchard and will act as a source for infestation of the trees in spring when the weeds die. In inland areas, the insects overwinter mainly as larvae; on the coast the other stages are more common in winter.

Injury Foliage, young fruit, maturing and mature fruit can be damaged. The injury is usually shallow, and the larvae spin fine webbing and feed from beneath its shelter. The most common injury is to young foliage and this can be important on nursery or young orchard trees. They roll the leaves together and feed within the shelter, and the damaged foliage has a ragged appearance.



Damage by very young light-brown apple moth larvae under the calyces of newly-set oranges.

Damage by light-brown apple moth larvae to newly-set oranges shows as prominent blemishing as the fruit grows.

In late spring in inland areas, citrus blossom is sometimes infested and webbed into clumps by the larvae, and newly-set fruits may be attacked. The feeding injury by the larvae on the surface of the small fruit shows up as severe blemishing when the fruit is mature. Often a small larva will feed under the calyx lobes of a very small fruit several weeks after blossoming, and this will show later as a shallow, ring-shaped blemish at the stem end of the fruit.

Maturing fruit may be attacked in autumn, and mature fruit may be attacked from spring onwards. The injuries are situated at points of contact with leaves or adjacent fruit. Feeding is confined to the rind and the albedo tissue. Attacked fruits may fall, but if harvested before they fall and if the damage is undetected during packing, they may decay during marketing.

Dispersal The moths are weak fliers and are unlikely to spread their infestation very far. They can, however, move from nearby wattles or weeds to citrus trees. Eggs, larvae and pupae could be transported on nursery trees to new sites. Dispersal is discussed further on page 98 under Apple Pests.

Control measures

NATURAL The many natural enemies of light-brown apple moth are referred to on page 98 under Apple Pests.

APPLIED Carbaryl 0.1 per cent or azinphos-methyl 0.05 per cent are effective. Spraying should be done when the infestation is first seen and, although only the outside canopy of the trees need be treated, it should be sprayed thoroughly.

Leaf case moth *Hyalarcta huebneri*

Importance and Distribution This case moth occasionally does serious damage to individual trees in a garden or orchard. All reports of attack on citrus are from coastal districts.

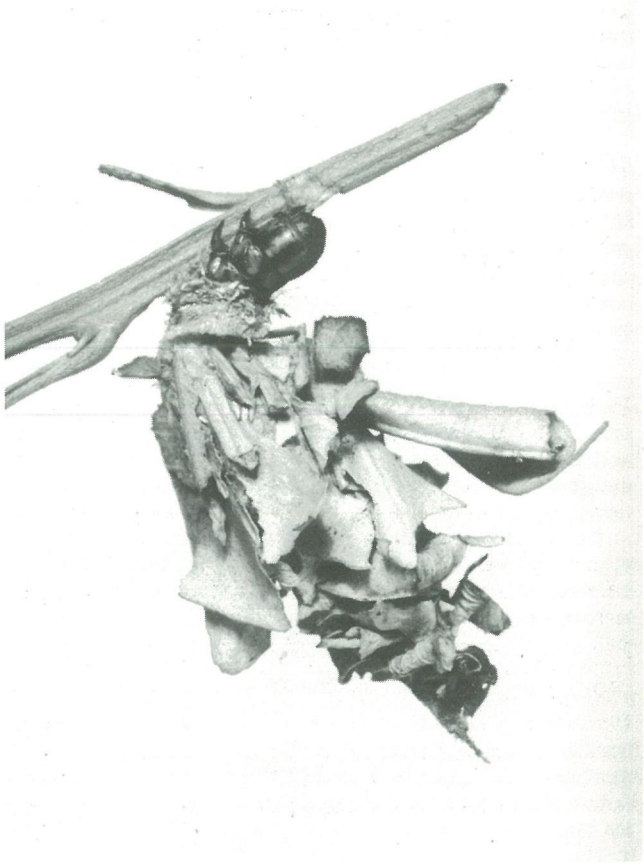
Conditions for Infestation The main condition leading to attack on citrus trees appears to be the proximity of other infested vegetation.

Plants attacked This native insect seems to prefer tough fibrous leaves to soft or succulent foliage. It commonly feeds on wattles, tea-tree, eucalypts or pines. Of the cultivated fruit trees, it prefers citrus.

Description and Life History The larva spends its life in a tough silken case made when it is young, and extended as the larva grows until the case is about 6.5 centimetres long. The case is ornamented with fragments of leaf cut from the host plant. When feeding, the larva projects its head and forelegs from the top of the case. It takes the case with it wherever it goes.

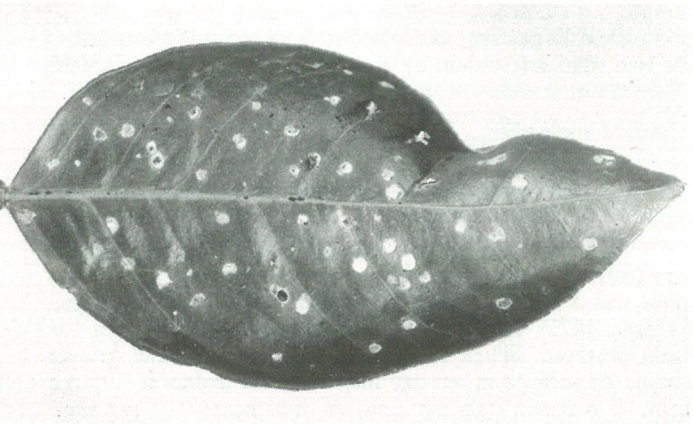
The full-fed larva pupates in its case. If the new adult is a male, it will measure about 2.5 centimetres across its outspread transparent wings. If it is a female, it will be wingless, with a furry abdomen, and does not leave the case.

The winged male mates with the female in her case. The latter then lays many eggs which accumulate in the bottom of the case. The young larvae hatch, leave the case by a bottom opening, and hang by fine silk threads until blown away. There are at least two generations a year.

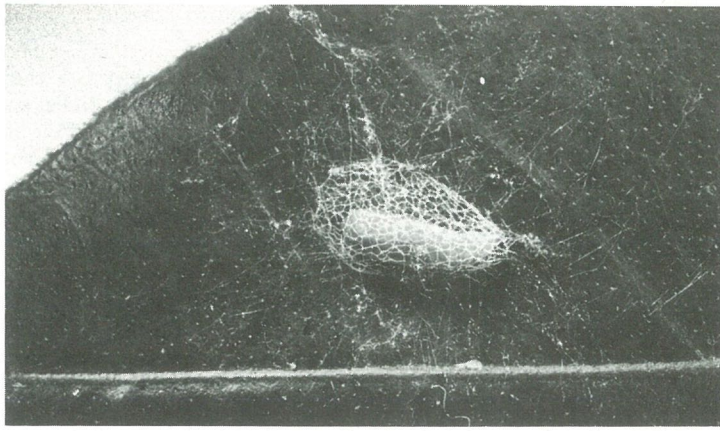


Leaf case moth larva in its case. (Length of case of fully-developed larva about 6.5 cm)

Injury The case moth larvae chew roughly-circular holes in citrus leaves, often eating through the leaf but leaving the second cuticle intact to give a 'window pane' effect. This injury resembles that inflicted by young snails. The case moth prefers mature leaves although it may attack young foliage and twigs. Only a few trees here and there are attacked, but the injury to these trees may be severe.



Leaf case moth damage on citrus leaf.



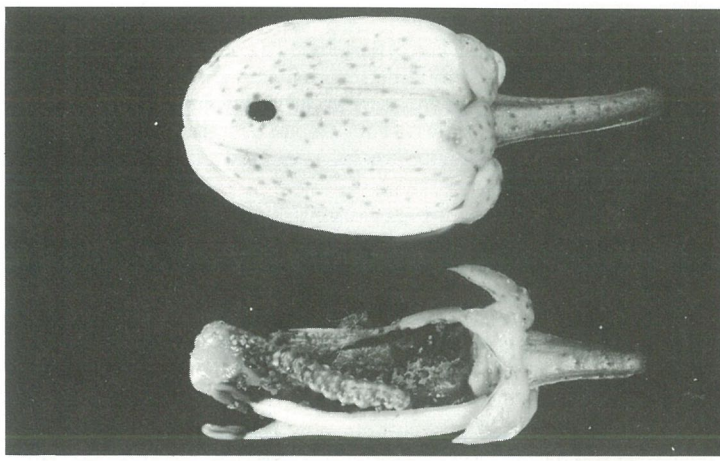
Lemon bud moth pupa on citrus leaf.

Dispersal Newly-hatched larvae which hang by fine threads are dispersed by the wind, and may also be carried by birds, insects and man. Once a female has reached maturity on a citrus tree there is a strong possibility that the tree will be attacked heavily by the next brood of larvae.

Control measures

NATURAL These insects are attacked in the larval and pupal stages by parasitic wasps.

APPLIED The damage is seldom severe enough to warrant spraying but, if it is considered to be necessary, carbaryl 0.1 per cent or maldison 0.1 per cent spray should kill the larvae.



Lemon bud moth larva and damaged buds.

Lemon bud moth *Prays parilis*

Importance and Distribution This moth infests lemon trees in the Central Coast districts of New South Wales and is probably elsewhere on the coast. It is not known to occur in inland orchards but is recorded in south-eastern Queensland. The small caterpillars feed in the flower buds and destroy almost every bud infested. The attack is most obvious in summer-autumn and over 50 per cent of lemon flowers formed at that time may be infested. Probably the damage restricts fruit setting only in seasons of light summer-autumn blossoming.

Conditions for Infestation The infestation is of significance only in the summer and autumn blossom of lemons.

Plants attacked This is a native insect but the wild hosts are unknown. Among cultivated citrus varieties Eureka lemon is the most susceptible; lime, citron and kumquat may also be infested. Second-crop blossoms of oranges growing close to lemons, when the latter were infested, have been seen to be lightly attacked.

Description and Life History The adult moth is less than 12 millimetres long, grey with brown markings on the wings, and bearing a brush of golden hair-like scales on the head. The egg is white and hemispherical. The larva is yellow at first and later becomes green and red-brown.

The moths are most prevalent in summer-autumn. Up to twenty eggs are laid on the red match-head-sized fruit buds, but only one larva survives per bud. The larvae may be full-fed in two weeks in summer, but development is much slower in the autumn. The larva leaves the bud and forms a lace-like cocoon, often at the edge of a curled leaf or at a twig junction. The shortest observed time for development from egg to adult is 22 days.

Injury Larvae hatch from eggs laid on the buds, bore into the buds and, while the blossom is developing to full size, eat the internal parts so that fruit setting is prevented. Sometimes a partly-developed larva enters a second blossom and feeds on the surface of the ovary. This damage may be seen as surface scarring on the mature fruit.

Dispersal Although the moths fly actively, it is thought that the adults do not disperse beyond the range of a few trees.

Control measures

NATURAL Natural enemies are not known.

APPLIED The tiny larva bores straight out of the egg into the bud, so chemical control would need to reduce the moth population in the orchard when most buds are young.

Control measures have not been practised by lemon growers but would be worthwhile if it is expected that summer blossoming will be light. Research has suggested that two sprayings should be sufficient using azinphos-methyl plus petroleum oil 1 per cent at an interval of two to three weeks when the red match-head-sized bud tissue is appearing in February.

Citrus leaf-miner *Phyllocnistis citrella*

Importance and Distribution Citrus leaf-miner is a common pest of citrus in Asian countries from Japan to India, and occurs also in Papua New Guinea and Africa. Since 1965 it has spread rapidly southwards from northern Queensland and now occurs in all coastal districts of New South Wales north of the Hawkesbury River.

It is a serious pest of nursery trees and newly-planted orchards. Continual infestation of the new leaves retards the necessary growth for satisfactory development.

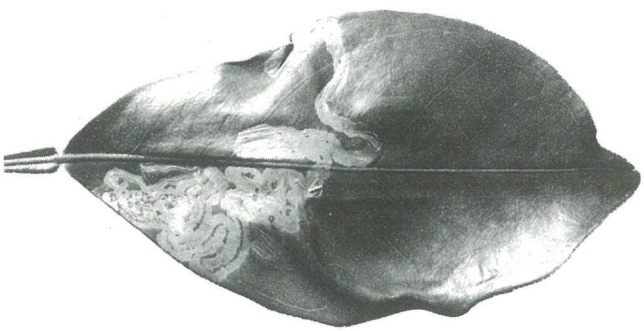
Conditions for Infestation Leaf-miner infestation becomes apparent in New South Wales from early summer through to late autumn. As it is the young tender growth which is infested, the problem is accentuated by weather conditions which promote successive bursts of new growth.

Plants attacked All cultivated citrus are hosts, and infestation of the finger lime, *Microcitrus australasica*, is also known.

Description and Life History The adults are minute silver-coloured moths, 2 millimetres long, with a wingspan of 4.5 millimetres. The larvae are narrow and approximately 3 millimetres long when fully grown. They tunnel beneath the leaf epidermis, leaving silvery sinuous 'mines' with a dark line of excreta in the centre of the mine.

The moths are nocturnal and rarely seen in daylight. The females lay eggs singly, usually near the midribs of the leaves. Larvae hatch from the eggs in approximately three days. They feed under the leaf epidermis for five to six days, ingesting sap, and pupate in a shelter made by rolling the edge of the leaf. Adults emerge from the pupae after about six days. Under favourable conditions the life cycle may be completed in fourteen to seventeen days.

Injury Infested leaves become distorted. As infestation can be very heavy, distortion of the young growth can be severe. When the infested leaf matures, the raised epidermis over the mines is lost and the damaged areas are white as they are without chlorophyll.



Citrus leaf-miner tunnels.

Dispersal This was rapid and widespread through New South Wales North Coast districts, and presumably effected by either wind carriage or the directional flight of adults. Dispersal into new areas is due to the movement of infested nursery trees. To limit the rate and extent of spread in New South Wales the sale of infested trees has been made illegal, and all citrus trees consigned to areas west of the Great Dividing Range must be dipped or drench-sprayed in dimethoate 0.03 per cent or diazinon 0.05 per cent and must be from a nursery certified to be free from infestation, by an inspector authorized under the *Plant Diseases Act*.

Control measures

NATURAL The natural enemies of the pest in New South Wales are not known. An unidentified wasp parasite has been detected in the larvae and pupae, but only at low levels of occurrence.

APPLIED Several insecticides control leaf-miner larvae, but none tested to date has been fully effective against the pupae (Tough, 1975). No long-lasting effect of spray treatment has been observed. When leaf-miner is active all young growth should be sprayed at ten-day intervals with maldison 0.05 per cent, or diazinon 0.05 per cent, or dimethoate 0.03 per cent. Dimethoate may damage Seville orange, kumquat and Meyer lemon trees.

Budworms *Heliothis* spp.

These caterpillars feed mainly on flower buds, blossoms and developing fruits and seeds, and damage a wide range of crops. In New South Wales they damage young green citrus fruits occasionally, but are rarely of economic significance. They bore round holes deeply into the fruits.

The caterpillars grow to a length of about 4 centimetres and are yellow, green, buff or red-brown, with black or brown markings.

For further details see page 219 under Bean Pests.

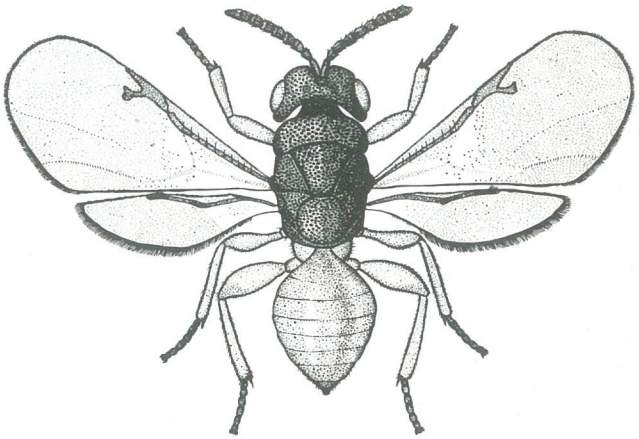
Fruit-sucking moths Noctuidae

Fruit-sucking moth larvae develop on wild or ornamental hosts where they are normally of little importance, but the adult moths may visit orchard trees to suck juice from ripe fruits. In Queensland the moths sometimes cause considerable fruit loss (Anon, 1951). They are generally unimportant in New South Wales, but have caused serious loss of navel oranges on home-garden trees in the Bourke district (Mosse-Robinson, 1968). *Othreis fullonia*

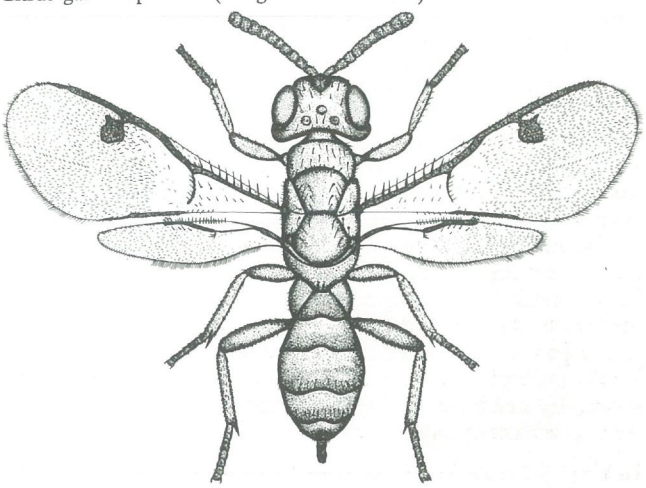
A fruit sucking moth, *Othreis fullonia*. (Wingspan about 10 cm)

(Clerck), *Othreis materna* (Linnaeus) and *Eudocima salaminia* (Cramer) are fruit-sucking moths known to occur in New South Wales.

The adult moths are large and stout-bodied, with a wingspan of approximately 10 centimetres. The forewings are dull, but the hindwings are brightly coloured. The moths rest outside the orchard by day and enter it by night to feed on fruit. The long proboscis is used to pierce the rind; the feeding hole is obvious, but may be mistaken for damage by an orange fruit borer larva. Decay sets in quickly around the hole.



Citrus gall wasp adult. (Length about 2.5 mm)



Epimegastigmus brevivalvis, parasite of citrus gall wasp. (Length about 2.5 mm)

HYMENOPTERA

Citrus gall wasp *Bruchophagus fellis*

Importance and Distribution This native insect occurs in the coastal districts of New South Wales and Queensland, and it has spread considerably since 1936 when its southern limit was at the Bellinger River (Gibson and Gellatley, 1968). It is well established in Sydney suburbs and is known to be in home-garden trees at Gosford, but there are no significant orchard infestations there. It is also present in home gardens in some towns in north-western New South Wales.

Conditions for Infestation The first requirement is proximity to an existing infestation. The geographical distribution suggests that areas with mild winter conditions are suitable for citrus gall wasp.

Plants attacked The finger lime, *Microcitrus australasica*, is the natural host of the citrus gall wasp pest. In inland northern New South Wales, the desert lime, *Eremocitrus glauca*, carries galls caused by a wasp indistinguishable from the pest species; it is thought to be a different strain because, while infestation induced on rough lemon resulted in galling, the life cycle was not completed (Anon, 1966). While all cultivated citrus varieties may be attacked there are marked differences in susceptibility. The rough lemon is undoubtedly the most susceptible, but grapefruit and cultivated lemons may be severely infested. Infestation is often irregular, with individual trees being heavily galled and similar trees only a short distance away being free.

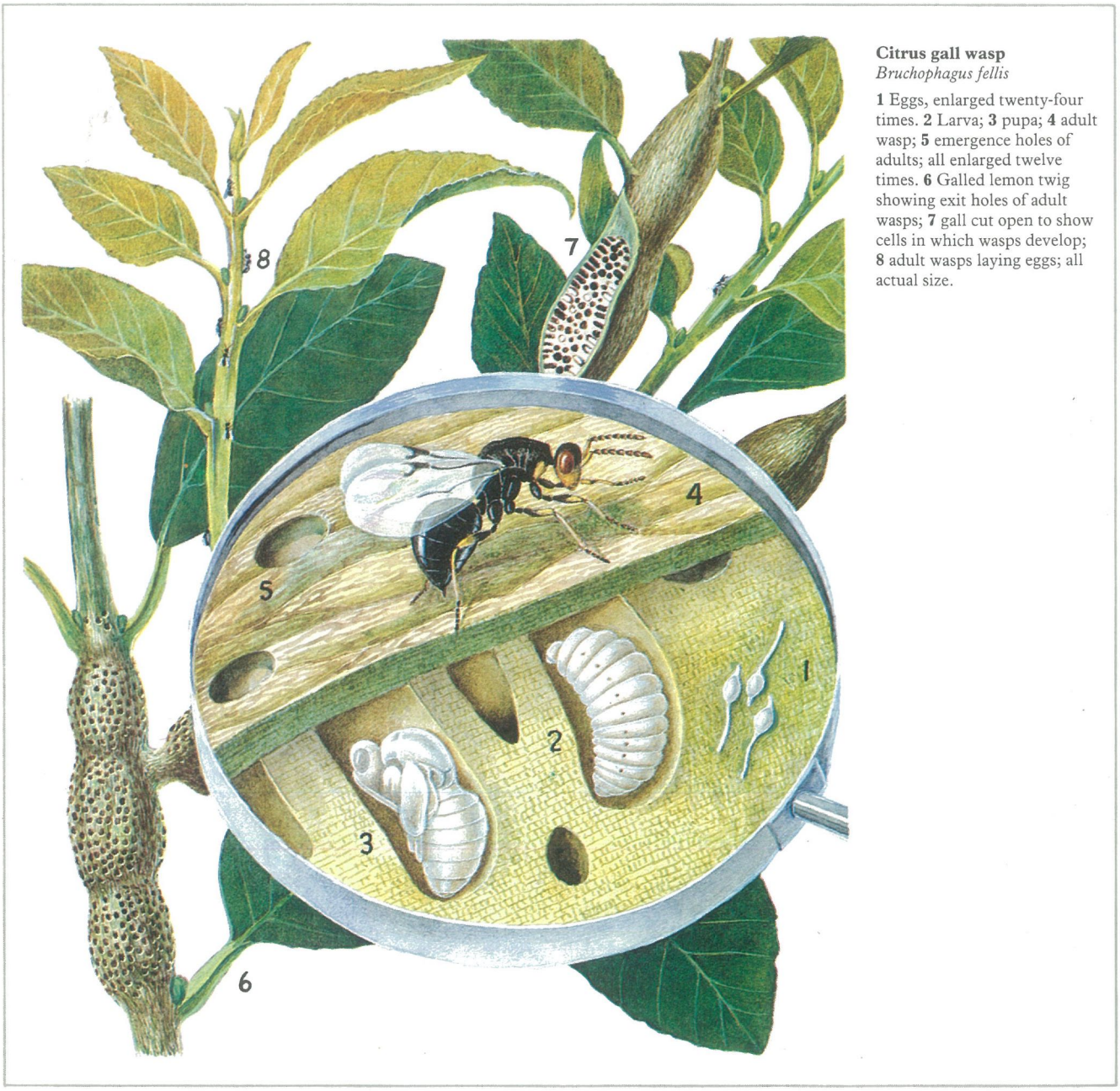
Description and Life History The adults are small black wasps, about 2.5 millimetres long, with brownish yellow faces. The larva is a thick-set legless white grub.

The adults emerge from the galls in spring, mainly September and October, mate and immediately lay eggs in green twigs, thorns, fruit stems and even the midribs of leaves. Each female may lay up to 120 eggs in the first 24 hours of her free life. The egg hatches after two to four weeks. The first-stage larva grows slowly until well into the next winter, then it passes through three more larval stages and a prepupal stage before it pupates in early spring. The pupal stage lasts two or three weeks. The life history has been described in detail by Noble (1936a).

About six weeks after egg-laying, infested twigs have a slightly roughened appearance. The galls, which result from an excessive production of woody tissue, become noticeable in December or January and reach their full size in autumn. In the gall the larva lies in a cell in the wood, and is surrounded by soft greenish tissue on which it feeds. The emergence of the wasps leaves many small round holes in the galled twigs.

Injury Moderate galling does not reduce production from a tree significantly, but heavy galling weakens it. A twig less than 6 millimetres thick may be converted to an elongated knot 25 millimetres thick with hundreds of emergence holes. Twigs may die and be replaced by weaker growth. Melanose fungus invades the dead tissue and kills more wood.

Citrus gall wasp damage to rough lemon twigs.



Citrus gall wasp
Bruchophagus fellis

1 Eggs, enlarged twenty-four times. **2** Larva; **3** pupa; **4** adult wasp; **5** emergence holes of adults; all enlarged twelve times. **6** Galled lemon twig showing exit holes of adult wasps; **7** gall cut open to show cells in which wasps develop; **8** adult wasps laying eggs; all actual size.

Dispersal Spread by the adult is only local. The wasps fly weakly and usually do not leave the tree from which they have emerged, but quickly lay eggs in it and die. However, there is probably some wind-borne transport of the adults. The most important means of spread to new localities is by the movement of infested young trees. This risk would be greatest with young trees from home gardens. Heavily galled twigs have been carried away as curiosities by people who do not appreciate the danger of infesting new areas.

Control measures

NATURAL Adult mortality is high. Some are trapped in the galls unable to cut through the bark and emerge, ants of the genus *Pheidole* kill many wasps as they emerge and, if emergence coincides with a heat wave, large numbers will die. Parasitism affecting the larvae in the galls can be very high; several species of parasitic wasps are involved, the most important being *Epimegastigmus brevivalvus* Girault (Noble, 1938).

APPLIED Cutting out and burning galled wood before the end of August is the only effective measure known to date. This gives satisfactory results when it is done thoroughly to all the trees in an area.

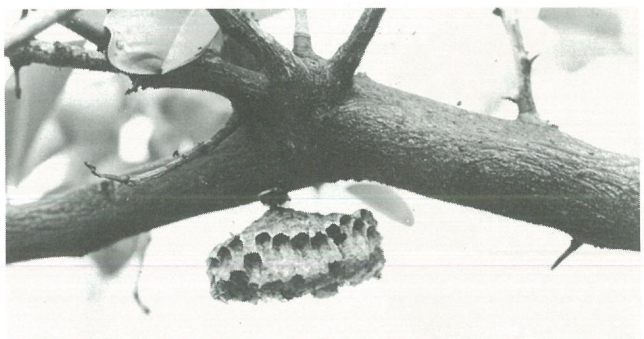
Regular inspection of nurseries in areas known to be infested has probably been responsible for preventing the wasp from becoming a pest of commercial orchards in any of the main citrus districts of New South Wales.

A safe and satisfactory method of disinfesting nursery trees from this pest is needed (Anon, 1966). Attempts to use hot water, ethylene dibromide and methyl bromide have not been promising (Anon, 1966).

Paper nest wasps *Polistes* spp.

In inland orchards, especially in Narromine and Bourke districts, these wasps can be a considerable nuisance. They nest in the trees and attack fruit pickers when disturbed. The sting is very painful. This hazard may make it difficult for growers to get harvest labour.

Young queen wasps overwinter in sheltered situations, often in the trees, and show little activity. In spring the queen begins to make a nest by building a few cells and laying an egg in each. The legless larvae are fed on nectar and masticated insects, chiefly caterpillars. When full-fed in two or three weeks each larva closes its cell and pupates. The new females (infertile workers) emerge, work on the nest and feed the young. The queen continues to lay eggs. The nest increases in size and may reach 15 centimetres across, hanging by its stalk with the cells looking like honeycomb. In the autumn, males and new queens are produced. The workers and males die and the fertilized queens overwinter before starting new nests in the spring.



Paper nest wasp nest.

Control measures Although the killing of caterpillars by the wasps is generally useful, they do occasionally have to be destroyed. The colonies are generally sprayed with a pyrethrum aerosol and the nests removed. Alternatively, a flare may be passed under the nests at night to disable the adults and allow the nests to be removed.

The wasp population is smaller where organophosphorus insecticide has been used for scale control.

Ants Formicidae

Many species of ants inhabit citrus trees and their role is generally harmful. They help and encourage scale insects, and their constant activity around the scale colonies discourages parasites and predators. According to Ebeling (1950), *Metaphycus helvolus* Compere, a wasp parasite of black scale, is affected very adversely by ants. On the other hand, the sluggish and relatively-ineffective scale-eating caterpillar, *Catoblemma dubia* (Butler), is only slightly affected by them. Way (1934) showed how greatly ants assisted brown scale in Zanzibar by taking away the honeydew that would otherwise choke the colony. The ants also carried young scales to new feeding sites. Bess (1958) showed that colonies of green scale in Hawaii disappeared in four months if ants were kept away from them, while ant-attended colonies thrived.

In experiments at Dareton, New South Wales (Hely and Duncan, 1959), control of soft brown scale by spraying was improved by treating the trunks and soil surface beneath the tree, and nearby nests, with dieldrin 0.5 per cent to control ants. The use of granular formulations of certain chlorinated hydrocarbons against Argentine ants, *Iridomyrmex humilis* (Mayr), in citrus orchards in California demonstrated the importance of this pest in protecting scale insects (Musgrove and Carman, 1965). The main agricultural threat posed by the Argentine ant in New South Wales is considered to be its interference with the natural control of scale and other sucking insects, especially on citrus.

Ants may occasionally damage citrus trees by direct attack. In coastal districts of New South Wales an ant, *Polyrachis ammon* (Fabricius), which is about 9 millimetres long and has a golden-coloured abdomen, sometimes nibbles the margins of young citrus leaves which then become cupped as they mature. The injury is not very important and is restricted to the outside rows adjoining bushland, but it can reduce the vigour of young trees. The ants usually nest in fallen logs. It is suggested that treating the nests with chlordane would overcome the trouble.

DIPTERA

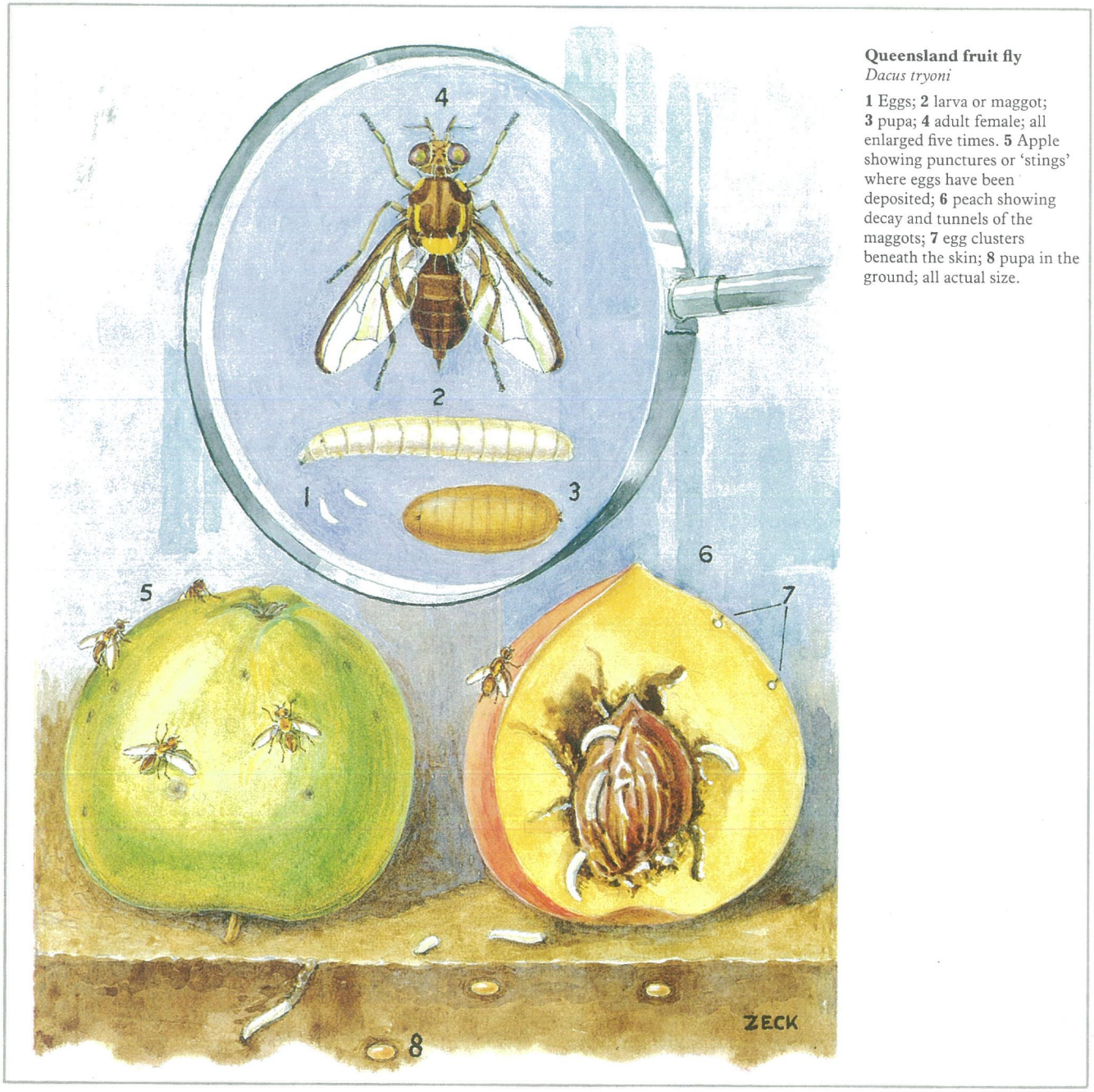
The Queensland fruit fly is the only fly pest of citrus in New South Wales. Citrus fruits generally do not suffer much loss from Queensland fruit fly attack, but they can be infested and this causes restrictions on interstate and overseas marketing.

Larvae of the island fruit fly are common inhabitants of fallen citrus fruits in coastal districts. This fly lays its eggs only in damaged fruits so it is not a pest species.

The Mediterranean fruit fly was previously a well-known pest in New South Wales but has not been present for the last 40 years. It is generally assumed that Mediterranean fruit fly was displaced by Queensland fruit fly.

Queensland fruit fly *Dacus tryoni*

Importance and Distribution This native insect pest was first described by Froggatt in 1897, although it had been known for many years (May, 1963). It occurs regularly in coastal New South Wales; inland, fruit flies are commonly reported north of a line between Sydney and Bourke, but south of that line they are recorded less frequently. Freedom from fruit fly in the Murrumbidgee Irrigation Area and Murray River areas is important for the export marketing of citrus and for interstate marketing to Victoria, Tasmania and South Australia. To reduce the



Queensland fruit fly
Dacus tryoni

1 Eggs; **2** larva or maggot; **3** pupa; **4** adult female; all enlarged five times. **5** Apple showing punctures or 'stings' where eggs have been deposited; **6** peach showing decay and tunnels of the maggots; **7** egg clusters beneath the skin; **8** pupa in the ground; all actual size.

risk of fruit fly occurrence in the inland orchard areas as a result of spread from home-garden trees, maldison–protein hydrolysate bait-spraying is commonly carried out as a routine in inland towns, generally according to the method described by Jones and Skepper (1965).

It should be emphasized that although fruit fly is of considerable importance to the citrus industry, resulting as it does in serious restrictions on marketing, the actual loss of citrus fruits by fruit fly attack in New South Wales is small. In well-tended orchards, fruit fly damage is of slight significance. However, because of the effects of quarantine barriers on trade, fruit fly is regarded as a major problem. Disinfestation treatment, by ethylene dibromide fumigation or low temperature storage (Leggo *et al*, 1965), is sometimes given to harvested fruit to free it from the possibility of carrying fruit fly.

Conditions for Infestation Fruit fly populations develop best in warm moist weather, such as in wet summers and autumns in New South Wales. Under these conditions they readily lay eggs in ('sting') mature and over-mature citrus fruit and the larvae may develop successfully in them. If the flies are very numerous in mid-autumn, they may 'sting' maturing fruit, such as main-crop navels, but usually the larvae do not develop successfully in them.

Generally fruit flies attack citrus only when other crops more suitable for the build-up of the population are unavailable. As

citrus fruits are a poor medium for maggot development, little fly population build-up will occur in citrus orchards. However, citrus trees are commonly used for shelter by overwintering adult flies.

Plants attacked Queensland fruit fly is a pest of most commercial fruits. All citrus varieties of commercial importance can be infested by fruit fly but the likelihood of attack on them is determined by the times when they mature and are harvested. Mature and especially over-mature citrus of any variety may be attacked when the pest is abundant. Thus second-crop fruit is attacked more than main-crop fruit, and may be 'stung' while main-crop fruit on the same tree escapes.

Having regard to usual harvesting practices, the following summarizes the likelihood of attack on main-crop fruit of citrus varieties.

Navel oranges: Maturing fruit may be 'stung' in mid-autumn. This ceases with the onset of cold weather. There is usually no development of larvae. Mature fruit retained on the trees in spring is susceptible to infestation.

Valencias: These are rarely attacked before the end of December, but from then on they are increasingly vulnerable.

Homasassa, Joppa, Siletta and Mediterranean Sweet oranges: Early maturing types may be 'stung' in the autumn, as may fruit allowed to remain on the trees in spring.

Seville oranges: When allowed to remain on the trees in spring, these fruits are particularly susceptible and may be attacked from late August onwards.

Lemons: Winter-crop fruits remaining on the trees in spring may be attacked from October onwards. Summer-crop fruits are susceptible in summer and autumn in home gardens, but infestation is rare in commercial orchards.

Grapefruit: Maturing fruit may be 'stung' in autumn. Mature fruit may be attacked from spring onwards.

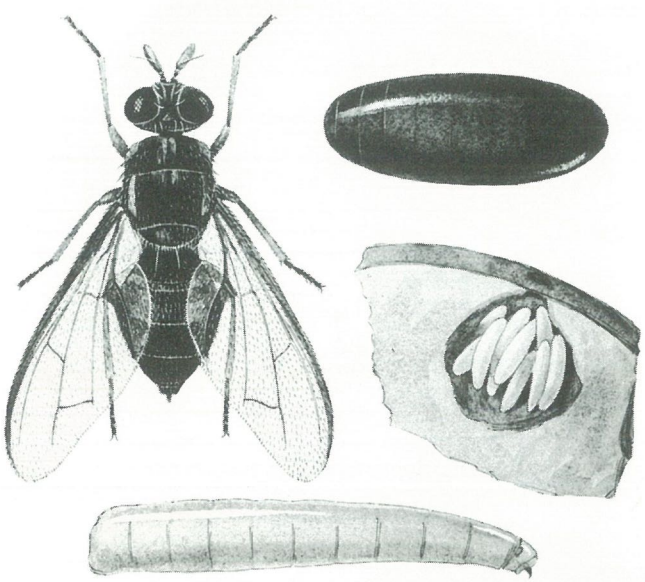
Mandarin: Early varieties are very susceptible in early autumn. Late varieties retained on the trees are readily attacked in the spring.

Kumquat: Summer-crop fruits are commonly attacked. Winter-crop fruits may suffer slight attack in autumn and, if retained on the trees, are attacked readily in the spring.

Fruit fly larvae often do not develop well in infested citrus and this depends on the fruit variety and its maturity. Some discussion of factors influencing suitability for development of larvae has been offered by Friend (1957). In artificial infestation tests, he found that contact with the oil in the rind of all citrus varieties killed eggs and young larvae. He also observed that in winter the albedo (pith) of main-crop Valencias and Eureka lemons was unsuitable for larval development whereas normal development could proceed in the pith of Wheeny grapefruit, old second-crop Valencias and Washington navels.

Description and Life History The adult Queensland fruit flies are active insects which move quickly and jerkily. They are about 7 millimetres long, and reddish brown with yellow markings. The female has a pointed abdomen with a needle-sharp retractable egg-laying organ, or ovipositor, at the tip.

The eggs are white, banana-shaped and nearly 1 millimetre long. About six at a time are placed approximately 3 or 4 millimetres into the fruit in a flask-shaped cavity made by the ovipositor. They hatch in two or three days. In citrus fruits many eggs fail to hatch and many young maggots die. The maggots are creamy white, legless and taper to the front end. They have paired fine black mouth hooks which are used to tear at the fruit tissue. If removed from the food, the maggot can 'skip'. It bends double, grips the posterior end of its body with its mouth hooks, braces its body muscles and lets go suddenly, springing as far as 15 centimetres. Many related maggots can jump in this way.



Queensland fruit fly – adult, eggs in fruit, larva and pupa. (Length of larva about 9 mm)

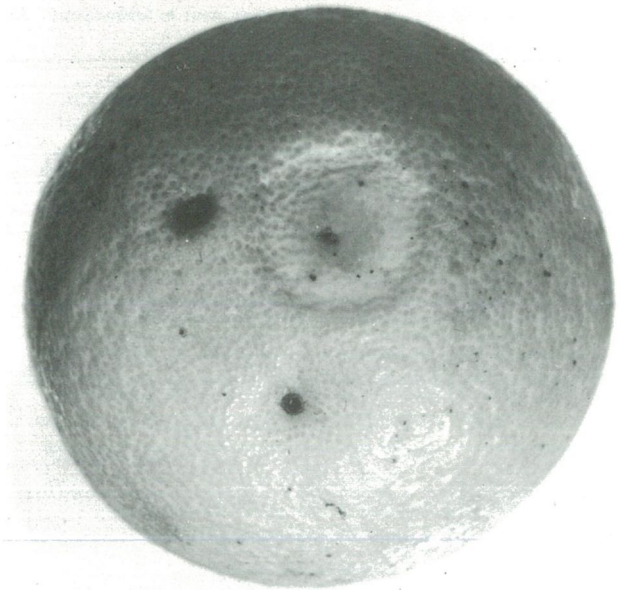
The full-fed larva, about 9 millimetres long, pupates by forming a brown barrel-like shell out of its own skin. Usually the larva burrows into the soil to pupate. The larval and pupal stages each take from about nine days to several weeks, depending on temperature. At least a week elapses before the new adult female lays eggs. The adults can live for many weeks and continue to lay eggs. Honeydew from aphids and scale insects is generally regarded as the principal source of food for the adults. Four or five or more overlapping generations may develop during spring, summer and autumn in coastal New South Wales if suitable fruits are available.

Activity is much reduced in winter, but does not cease in coastal New South Wales. It is possible to find some larvae in out-of-season fruits, but most of the overwintering population consists of adults that shelter in quiet situations. They can be seen commonly on citrus foliage on warm days in winter. In August, the activity of the overwintering flies increases and mature kumquats, mandarins and grapefruit may be 'stung'.

During spring, hosts other than citrus are important for the build-up of the new season's populations of fruit flies. Loquats especially are heavily infested.

Injury The females puncture and lay eggs in many different fruits. The maggots hatch and quickly destroy the fruit, partly by their feeding and partly as a result of the rotting that follows the invasion.

The first indication that green, maturing citrus fruit has been 'stung' is colouring of the area where the eggs were laid. Soon the colour spreads all over the young fruit, which then falls. The site of the 'sting' is usually marked by an exudation of clear or brownish gum. When almost mature fruit is 'stung' it may fall to the ground without showing any indication of attack. A few days later a soft spot will develop into a circular greyish brown area of yeasty breakdown with maggots in the pulp. Much of the damage following fruit fly attack in citrus is from mould decay rather than maggot development.



Queensland fruit fly 'stings' (oviposition sites), with decay commencing.

Dispersal The adults are strong fliers capable of travelling some miles in a lifetime. In other countries related flies have been shown to travel up to 64 kilometres (wind-assisted) over water. For the introduction of the pest to a previously fly-free environment, the transportation of infested fruit is the main means of travel. Fruit may be carried to new areas and discarded, maggots may leave fruit in transit, or pupate in packaging material or vehicles from which the adults escape later.

Control measures

NATURAL Native parasites affect fruit fly in native fruits, but are not successful in commercial fruits. Many attempts have been made to introduce more effective larval and egg parasites of Queensland fruit fly (Snowball, 1960), but none has yet had any notable success.

APPLIED Fruit fly damage to most citrus varieties can be avoided by ensuring that susceptible fruit is harvested before the flies become numerous and active.

Main-crop mandarins and navels will mostly escape damage if harvested before September, as will Valencias if they are harvested before the end of December in most years. Kumquats can be pruned to produce fruit in winter, and then harvested before the end of August. Summer kumquat fruits should be removed before they become ripe enough for the flies.

Apart from summer-crop lemons, second-crop fruit is not valuable and should preferably be removed from the trees. Summer-crop lemons are not attacked much in orchards. In home gardens they may be attacked heavily, and this is best overcome by picking and storing the fruit before it shows colour.

When stinging of citrus is expected, bait-spraying against adults with maldison-protein hydrolysate (maldison 25 per cent dispersible powder 30 grams-protein hydrolysate liquid 22 per cent 30 millilitres-water 600 millilitres) will give good protection. Bait-spraying should begin at the first sign of stinging or when the flies are amongst the trees in large numbers, and it may be necessary from December onwards for mature Valencias. The bait spray should be splashed or sprayed on to patches in the trees using not less than 60 millilitres of bait per tree, and avoiding the fruit as far as possible. The bait spray can cause fruit-burn and foliage injury. The aim should be to apply the bait to foliage, preferably on the lower surfaces, while avoiding a heavy concentration of bait in any one place.

When the treatment is begun the whole area should receive a bait-spray including windbreak trees and other shrubs where flies may be sheltering. After the first thorough baiting, which normally reduces the fly population sharply, subsequent baitings may be less liberal; alternate rows of trees can be treated at each application after the first. Flies are attracted to the bait from quite a distance. If rain does not wash it off, re-baiting need not be done more than once a week.

Mist blower equipment may be used to apply bait-spray and this greatly reduces the time needed for the job.

The organophosphorus materials, dimethoate and fenthion, are very effective as cover sprays over fruit to prevent maggot development in fruit for several weeks after spraying. They have considerable value for fruits other than citrus. As they do not prevent 'stinging', which is usually followed by entry of decay, they are not very suitable for preventing losses from fruit fly attack in commercial citrus orchards. They do have a place in preventing maggot development in home-garden citrus.

In New South Wales people owning or occupying land on which fruit trees are growing are required, under the *Plant Diseases Act 1924 (as amended)*, to take the following steps to control fruit fly.

(i) To pick up all fallen fruit at intervals not exceeding three days.
(ii) To destroy all infested fruit whether from the tree or the ground, at intervals not exceeding three days, by burning, or by boiling, or by keeping it under water for at least ten days, or by keeping the fruit for several days in a closed plastic bag exposed to the sun.
(iii) To apply either poison bait spray or full cover sprays.

Maldison-protein hydrolysate bait spray for fruit fly control can cause fruit blemishing.

The poison bait spray is maldison-protein hydrolysate as described above. The cover sprays must contain dimethoate or fenthion and must cover all fruits completely. The concentration specified for citrus is 0.06 per cent applied at both eight and seven weeks before harvest.

The most suitable times for application to home-garden citrus usually will be:

Navels – first week in September and again one week later.
Valencias – first week in December and again one week later.
Lemons – first week in October and again one week later.

Note: Dimethoate should not be used on Seville orange, kumquat or Meyer lemon as it can injure these trees.

Lures of caneite blocks impregnated with p-hydroxyphenyl butanone plus p-acetoxyphenyl butanone, as attractants, and maldison insecticide, to kill flies quickly, set in open-ended cans, are used widely for scouting and to indicate changes in fruit fly numbers. They attract Queensland fruit fly males strongly, and the males are killed and most of them are retained in the can. These lures do not protect against fruit infestation, so do not replace bait-spraying and cover-spraying.

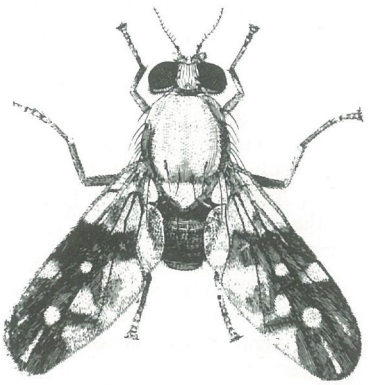
Island fruit fly *Dirioxa pornia*

This native insect is not a pest fruit fly, as it only infests fruit that has already suffered some skin damage. The maggots are found very commonly in fallen citrus fruits in coastal districts. It is necessary to distinguish them from Queensland fruit fly maggots so that observations of them do not provide incorrect records of Queensland fruit fly occurrence. The maggot resembles that of the Queensland fruit fly, but may be distinguished by microscope examination of the anterior and posterior spiracles to detect characters described by Gurney (1912).

Island fruit fly occurs in coastal areas and is most commonly seen in citrus orchards in summer and autumn walking slowly over leaves and fruit and moving its wings alternately backwards and forwards. The adult is a little smaller than the Queensland fruit fly. The thorax and abdomen are brownish yellow, and the abdomen has a black tip. The wings are strikingly mottled with dark brown to black markings with clear spots in the dark areas.

The ovipositor of the female is soft and blunt and incapable of piercing the rind of sound citrus fruit. The eggs are deposited in damaged rind of citrus fruits or in the oviposition punctures of Queensland fruit fly, but they are never deposited in sound fruits.

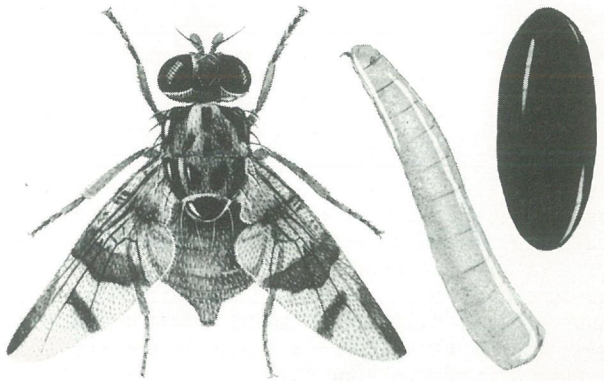
Island fruit fly has not usually been bred from fruit other than citrus and native black apple, *Planchonella australis*, but there have been occasional records of occurrence in rotting apples and peaches.



Island fruit fly.

Mediterranean fruit fly *Ceratitis capitata*

This severe pest of fruit in many other countries disappeared from New South Wales about 40 years ago. In Australia, it is present now as an established pest only in Western Australia. At times outbreaks have occurred in Victoria, Tasmania and, particularly, in South Australia at Adelaide and Port Augusta. It has never been found in Queensland (May, 1963).



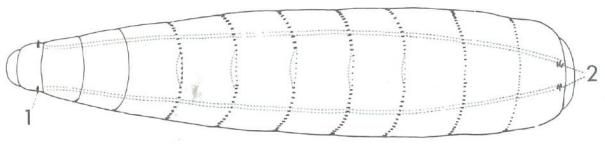
Mediterranean fruit fly – adult, larva and pupa. (Length of larva about 9 mm)

Mediterranean fruit fly was first discovered in Australia in 1897 near Perth, Western Australia, and was found near Sydney in 1898 (Froggatt, 1899b). It became a well-known pest in the Sydney-Newcastle area and was found in western and south-western areas of the State. A special investigation at Gosford of this and other flies affecting fruit was reported by Gurney (1910, 1911, 1912) and guides to identification of the larvae were given.

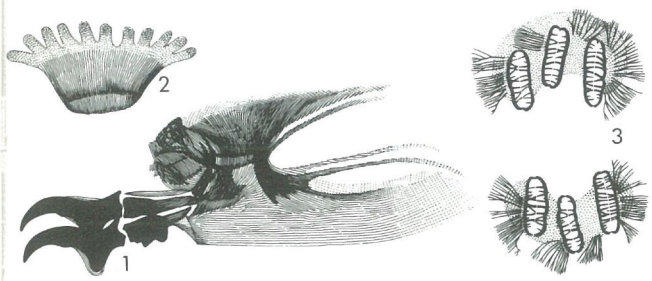
Mediterranean fruit fly remained an important pest of fruit, especially on deciduous tree fruits and Seville oranges, until the late 1920s when occurrences of the Queensland fruit fly became increasingly frequent. During the early 1930s, it was quite usual to breed both Queensland and Mediterranean fruit flies from one infested citrus fruit.

The most recent record of Mediterranean fruit fly breeding from fruit collected in the field in New South Wales was in 1941. Allman (1939) has discussed the apparent displacement of Mediterranean fruit fly by Queensland fruit fly and reported that, in cage tests, Queensland fruit fly females frequently laid eggs in egg punctures which had been made in fruit by Mediterranean fruit flies.

The adult fly is smaller than the Queensland fruit fly and generally yellow, with black and silver markings on the thorax. The wings have brownish bands and spots, and are held in a drooping and semi-spread attitude. The life cycle in Western Australia has been reported by Jenkins and Shedley (1956) and is generally similar to that of Queensland fruit fly.

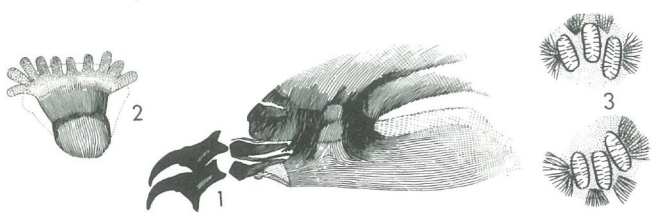


A A fully-developed fruit fly maggot viewed from above.
1 anterior spiracle
2 posterior spiracles



B Queensland fruit fly maggot.
1 mouth hooks
2 anterior spiracle
3 posterior spiracles

C Mediterranean fruit fly maggot.
1 mouth hooks
2 anterior spiracle
3 posterior spiracles



D Island fruit fly maggot.
1 mouth hooks
2 anterior spiracle
3 posterior spiracles

Fuller's rose weevil *Asynonychus cervinus*

Importance and Distribution This weevil was first recorded in New South Wales in a pot plant (Gurney, 1934). The first field occurrence was reported by Hely (1937, 1948), and since then it has spread all over the State in suitable situations. It is probably a native of South America and is an important pest in many countries. In New South Wales it is best known on citrus. The adults eat the leaves and the larvae the roots. After it was first recorded it multiplied greatly in some areas and caused serious defoliation, but it appears to have reduced to the status of a minor pest.

Conditions for Infestation Temperate to subtropical conditions suit the weevil best. Cold winters check its development, but do not kill it in New South Wales. The unusual heat wave of January 1939, with a shade temperature of 48°C, did not seem to harm either the adults or the larvae. Water-logged soils are unsuitable for the larvae.

Plants attacked The adult commonly feeds on a wide range of broad-leafed plants including orchard trees, many garden ornamentals, and many weeds. It is particularly partial to the weeds fat hen, *Chenopodium album*, and Paddy's lucerne, *Sida rhombifolia*. Attack on fruit trees is often obvious only near weedy ground.

Description and Life History The adults are strongly built, grey-brown, about 8 millimetres long, and have short broad 'snouts'. They have a faint crescent-shaped white mark on each wing cover.

No males are known. All adults lay eggs, and stick them in masses of 20 to 30 eggs on a substrate. This may be under stones, under bark, under calyx lobes on fruit, or in curled dead leaves. A favourite situation is in citrus leaves which spiders have drawn together with webbing. Eggs may hatch in four to eight weeks but those laid in late autumn do not hatch until the spring. Eggs can remain viable for many weeks, if the weather is dry.

The young larvae are legless orange grubs. They drop from the egg mass and enter the soil. They feed on roots and become translucent first and then white. When full-fed they are only 6 millimetres long, thick-set and white with a brown head. They curl to a half-moon shape when disturbed. In a citrus orchard most are found about 15 to 20 centimetres below the soil surface under the trees, and they are more numerous near the trunk than farther out.

The total time required for incubation, larval growth and pupal development is about a year.

Adults emerge from pupal cells in the soil in the warmer months of the year, usually after rain, live for about two or three months and lay about 200 eggs each. They feed mostly at night and shelter during the day, often in groups, in rolled leaves or among fruit clusters.

Injury The adult feeds by chewing around the margins of leaves, thus creating a coarsely-serrated edge. Sometimes only the stalk and midrib remain. Most damage is to mature leaves. Citrus fruit is not attacked.

Larvae attack the roots; the most important damage they do in citrus is nipping-off root fibres with a little pitting or gouging

Fuller's rose weevil damage to orange leaves.

of the larger roots. The roots of heavily infested citrus trees may be long with tufts of fine roots at the end, as they have been almost stripped of the fine fibrous roots along their length. The adult weevils show a preference for replant trees in old groves, and in such a situation loss of leaf tissue may retard growth. Damage by larvae, even in heavily infested trees, does not seem to be important. Well-tended trees appear to be able to support a considerable population of Fuller's rose weevil larvae without obvious production loss.

Dispersal The rate at which this weevil has been distributed around the world, and throughout New South Wales, is striking. This has been made possible by the insects' capacity to cling inconspicuously to many different sorts of objects, such as bins and boxes used for harvesting, to survive starvation and to eat almost any vegetation. Not only adults but also egg masses are easily transported. Young larvae can live for ten days without food after hatching and before reaching the soil. The adults cannot fly.

Control measures

NATURAL Soil conditions are important; water-logging is unfavourable to larvae and drought can prevent adult emergence. Natural enemies seem to be few.

APPLIED Good weed control in an orchard is insufficient to suppress weevil numbers. No satisfactory method of controlling larvae in soil has yet been demonstrated in New South Wales, but Elmer (1960) states that, in California, dieldrin or azinphos applied to the soil is effective for up to two months.

For trees attacked by the adults, spraying with carbaryl 0.1 per cent is suggested when the weevils are first seen feeding on the leaves. The trunk and soil should also be well covered by the spray to kill the newly-emerging weevils.

Elephant weevil *Orthorhinus cylindrirostris*

Importance and Distribution This weevil was amongst the earliest citrus pests to be recorded in New South Wales, as it was described as such in 1862 (Olliff, 1890). The species is a native, is widespread in inland as well as coastal districts, and breeds in many native trees.

Conditions for Infestation Elephant weevils are strongly attracted to unhealthy citrus trees. The causes of unthriftiness may be many and include water-logging, drought, root disease, severe erosion and over-crowding.

Plants attacked Among native hosts *Eucalyptus* spp. are probably the most important, but many others are attacked. Orchard trees, especially citrus (all varieties) but also grapevines, apple, apricot and peach, may be infested.

Description and Life History The adult weevils may vary in size from 8 to 20 millimetres long, a difference which results presumably from the conditions in which they develop. Their bodies are densely covered with scales which vary from grey to black. The wing covers have four distinct prominences towards the tip and smaller ones near the base. Another pair on the thorax slightly overhang the head. The prominences bear longer scales. The front legs are longer than the others, with large tarsal segments. The proboscis is prominent, with antennae towards the tip.

The eggs are deposited beneath bark. The grub is soft and fleshy, creamy yellow and legless, and reaches a length of nearly 20 millimetres. The pupa is soft and white, with light brown developing wing covers.

Most beetles emerge during September and October, and eggs are laid shortly afterwards in holes drilled with the proboscis in a tree trunk, near the ground. The larvae tunnel for about ten months, the pupal stage lasts for two or three weeks, and the adults emerge a year after the eggs were laid.

Injury Some damage is caused by adults chewing square or rectangular pieces of green bark from twigs and branches. The larvae, however, cause the real damage. They bore into the wood as soon as they hatch. First they tunnel downwards, at a level well below the bark, through the trunk or butt and into the root.

Elephant weevil emerging from nursery tree.

Later they turn around and make their way upwards. The full-fed larva pupates within the trunk in a short horizontal cell between a few centimetres and a metre above ground level.

One or two larvae in a root may not cause much harm, but several larvae in a root will seriously affect it. When an infested root is cut across, each tunnel shows up as a round white area of tightly-packed sawdust-like material which is characteristic of this beetle's work.

When the weevil emerges from the pupal case it cuts a clean round hole to the surface. Aged nursery trees are commonly attacked, and escape tunnels cutting across the conducting system will cause sudden wilting of the tree.

Dispersal The adults are strong fliers and travel mostly at night. Trees in a weakened condition will almost certainly be infested. Larvae could arrive at an orchard in nursery trees, but this is unlikely if yearling trees are planted.

Control measures

NATURAL Little is known of the natural means of population regulation.

APPLIED As far as possible, trees (especially young trees) should be grown without severe checks in growth when the beetles are emerging in late spring or early summer. If infestation is expected, it may be helpful to spray the trunks and butts of trees lightly with chlordane 2 per cent to kill the adult weevils.

Dicky rice weevil *Maleuterpes spinipes*

Importance and Distribution Why this common name came to be used for this native weevil is not known. Until after World War II, the weevil was an important pest in coastal districts as it blemished young fruits and damaged new foliage. In 1927, it was recorded only around Sydney and at Kurrajong (Woodhill and Allman, 1927), but later it became a pest in the Gosford–Wyong and Moorland districts. In some districts it became routine practice to prevent infestation by banding the trunks of citrus trees with sticky material, trimming the lower branches to keep them off the ground, and preventing weed growth from reaching the leaves. The advent of DDT promoted good and less costly control by spraying the trunk and lower foliage as well as the ground beneath the tree. But in the 1950s the weevil became a much less important pest, and the reasons for this are not understood. No parasite or predator was known to have increased in numbers, and there had been no important change in the use of pesticide sprays.

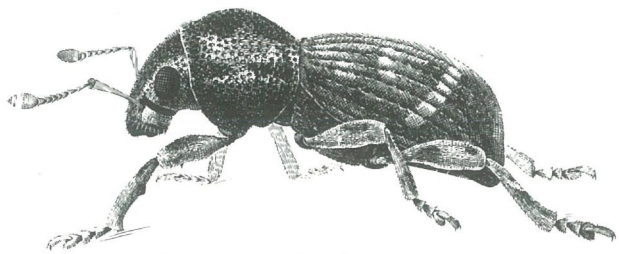
Conditions for Infestation Adult weevil activity was closely governed by rainfall and was greatest during years with good rains in spring and summer. It was not unusual for a large population of the weevils to be present but inactive in dry weather, and then to feed voraciously on new foliage after rain falls.

Land which had been newly planted after clearing the native bush was most likely to be heavily infested. The immature stages preferred heavy loam soils to sandy soils.

Plants attacked Dicky rice weevil is apparently restricted to citrus trees and to native members of the same family, Rutaceae. Among the citrus varieties, oranges and grapefruit are more commonly attacked than lemons.

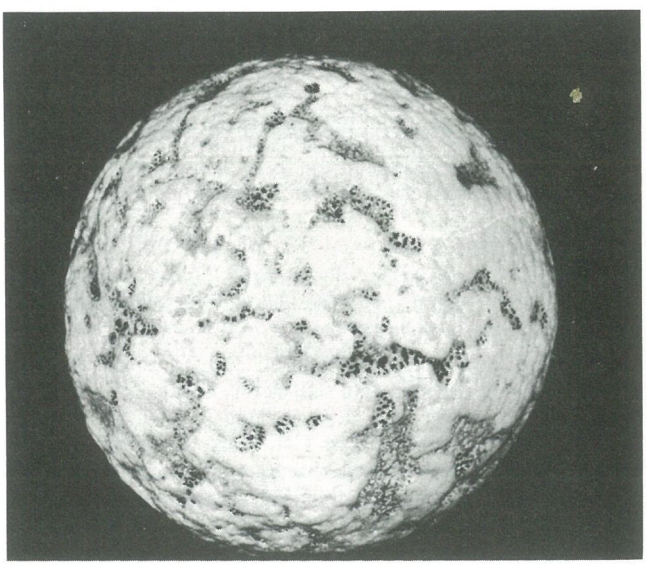
Description and Life History The adult is a small but robust brown weevil up to 3 millimetres long, with grey-white markings on the back and legs. The wing covers have prominent shoulders. The wings are normal, but the weevil has never been known to fly. The males have long curved spines at the middle of each front femur. The eggs are less than 0.5 millimetres long. The larvae are white legless grubs up to 3 millimetres long, each with a circle of reddish brown bristles on the upper surface of the last segment.

Large numbers of adults emerge from the soil during October and November. During dry weather they feed on fallen ripe fruits, the bark at the base of the trunk, or exposed surface roots. After rain they swarm up into the trees and feed on the rind of young fruits and on young foliage. The eggs are laid in the soil, and the larvae live in the soil and feed on citrus roots, but have not been shown to cause any appreciable harm. They pupate in the soil. It is believed that most larvae live from early summer until the following spring. Gallard (1920) has suggested that there may be two generations each year.



Dicky rice weevil. (Length up to 3 mm)

Injury The weevils chew leaf margins thus causing small saw-tooth indentations, and eat the rind of young fruits. The first is usually unimportant, but the fruit injury may cause downgrading of a high percentage of the crop. The damage is done mainly in late spring, but sometimes the same crop will be damaged further by an apparent second rise in beetle numbers in late summer. The injury to fruit is a network of irregular furrows which are white at first, but will be grey or black by the time the fruit matures.



Orange damaged by dicky rice weevil.

Dispersal The adults have wings but have not been observed to fly. They have been shown to crawl 12 metres over soil in a week. When shaken from a tree they feign death. It is possible for them to be transported in packages of citrus nursery trees, or in bins or boxes used for harvesting.

Control measures

NATURAL The natural enemies of this species are not known.

APPLIED Banding tree trunks with sticky material and controlling the growth of weeds and tree limbs is no longer regarded as practicable for the control of dicky rice weevil. Spraying with carbaryl 0.1 per cent can kill the majority of beetles soon after they emerge from the soil.

Citrus leaf-eating weevil *Eutinophaea bicristata*

This small weevil is quite a serious pest of citrus in south-eastern Queensland and occurs also in north-eastern New South Wales. It is grey-brown and very similar to the dicky rice weevil but it can fly, and the males lack the foreleg spines. The larvae and pupae are found in the soil under infested trees. Adults are abundant in the spring and as many as ten have been seen on one citrus leaf.

Injury is most serious on the lower parts of the tree, and all the lower leaves of an infested tree may appear to be grey as a result of the destruction of leaf tissue. The weevils chew small irregularly shaped patches from both surfaces of the leaves and heavy leaf-fall may result. Young fruits may also be attacked with subsequent down-grading at harvest.

It is expected that spraying with carbaryl 0.1 per cent would be effective against this species.

Leaves damaged by citrus leaf-eating weevil.

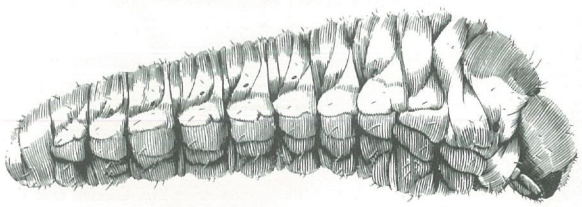
Fruit tree root weevil *Leptopius squalidus*

Importance and Distribution French (1893) referred to this weevil as 'apple root borer', and as one of the most destructive insects in the colony. Woodhill (1929) proved it to be the cause of a serious die-back condition in citrus trees at Windsor. Since the development of satisfactory control measures, it has been troublesome only occasionally and has not been important in the main citrus-growing areas. It is a coastal pest, also known to occur on the tablelands, but not in large enough numbers to cause serious damage.

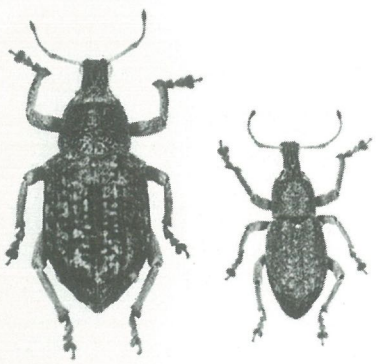
Conditions for Infestation River-flat country subject to periodic flooding is particularly susceptible to infestation. It seems that sometimes the beetles are carried by floods into orchards where river-flat soils encourage deep rooting of the trees, and this pest does its greatest damage on the deeper roots. The beetles are also favoured by heavy soils. They are seldom seen in sandy soils.

Plants attacked Friend (1945) recorded an alternative host plant of this native insect when both weevils and eggs, and typical larval root damage, were found on *Eucalyptus amplifolia*, the swamp gum. Probably other eucalypts are also attacked. Of cultivated trees, apples are the best known hosts, but other deciduous fruit trees are also susceptible.

Description and Life History These weevils do not fly. The adult female is about 2 centimetres long and grey-buff, with the typical weevil snout. The males are smaller. The eggs are 1 millimetre long and elongate-oval. The creamy legless grubs reach a length of 2 centimetres. The pupae are light-coloured and naked, and show the outlines of the adult body.



Fruit tree root weevil larva. (Length, when fully developed, up to 2 cm)



Fruit tree root weevil – female at left, male at right. (Length of female about 2 cm)

The eggs are laid at night in groups of 40 or 50 between two leaf surfaces glued together for the purpose. The egg mass is covered by a silky white film.

The eggs hatch in a week and the young larvae drop to the ground, bore down to the roots, and begin to feed in late winter. The full-fed larvae pupate in earthen cells close to the roots. In spring, the adults dig their way out of the soil and climb the trees. The greatest numbers of adults appear in September, but emergences do occur from August to November. The life cycle occupies a year, and adults have lived for ten months in the laboratory. They feed on young leaves and lay eggs during summer.

Injury The larvae cause the main damage. Deep furrows are eaten out of the thicker roots, and a heavy infestation will kill the roots. The deeper roots, a metre or more from the surface, are most frequently attacked. The injury by adults to the leaves is insignificant. The pest can destroy an orchard if conditions are suitable and no control measures are employed. A close watch should therefore be kept in situations likely to suit the pest, and control begun before damage can cause permanent injury. If trees become thin and sickly, and show general die-back and excessive leaf-drop, root weevil should be suspected.

Dispersal As the weevils cannot fly, they travel by crawling to a grove or within it, and they are known to be capable of travelling long distances. In addition, they are probably carried by flood water. The introduction of egg masses on nursery stock is considered unlikely. Beetles and larvae could be present on newly-cleared land; good soil preparation before planting citrus could guard against this risk.

Control measures

NATURAL The natural enemies have not been recorded in New South Wales.

APPLIED If root weevil attack is suspected, further evidence may be sought in several ways. In late winter, some trees in poor health and others that are healthy should be banded, as high on the trunk as possible, with sticky material or fly screen wire traps. Limbs should be trimmed to prevent them touching the ground and weeds controlled to force weevils to climb the trunk in order to reach the tree. Sticky bands should be 'freshened up' regularly to prevent weevils from crossing them. All bands or traps should be inspected at least weekly in spring and summer, and the weevils collected and destroyed. Woodhill (1929) records the collection of 65 000 weevils in a 7-hectare orchard in four months; 90 per cent of them were taken on 800 seriously infested trees.

An examination of the deeper roots of some affected trees will show the presence of weevils by their furrowed appearance, and larvae and pupae will probably be found also. In spring and summer, the adults may be found feeding on dock, *Rumex* sp., apparently a favourite food.

Sustained trapping will strikingly reduce the weevil population and lead to the ultimate recovery of the trees.

Spraying the trunk, lower foliage and soil under the tree in spring with DDT 0.1 per cent as three treatments – in early September, October and late November – to kill adults and young larvae falling from the leaves, has been successful. This use of DDT may stimulate scale and mite infestation so it is not recommended. Other insecticides have not been tested recently for this purpose.

White striped weevil *Perperus lateralis*

This weevil is a minor and localized pest of citrus and other fruit trees; it is occasionally troublesome at Mangrove Mountain where it was first recorded by Froggatt (1898). It is about 6 millimetres long, smooth and light grey with a white stripe running the length of each wing cover.

It may occur in very large numbers in the spring, and by gnawing buds and feeding on young shoots it can cause a severe set-back to young trees. The weevils feed at night, but large numbers of them can usually be found during the day sheltering in curled leaves, under bark and in similar situations. Beetles disappear in about November. The life history is unknown. They occur on plants growing only in sandy soil. They are also a pest of passionfruit and have been recorded on capeweed flowers.

Often the attack is severe in dry weather, and ends after rain which seems to disperse the weevils.

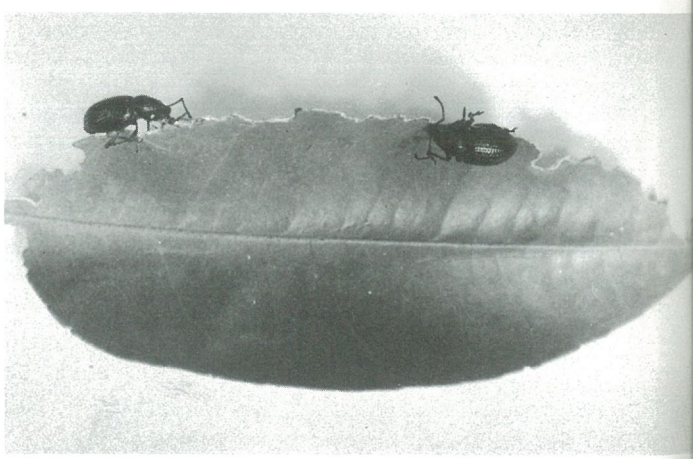
Control measures When treatment is essential, carbaryl 0.1 per cent should provide adequate control.

Apple weevil *Otiorhynchus cribricollis*

This weevil is occasionally a pest of citrus in south-western New South Wales. It attacks many hosts including apples, plums, roses and other ornamentals. The damage is caused by the night-feeding adults; they chew the edges of leaves giving them a saw-toothed appearance.

The weevils are about 9 millimetres long, shiny and dark brown. They emerge from the soil in early December and January, climb the trees at night to feed, and shelter in the soil by day. They can be numerous enough to strip young trees almost completely.

Control measures Spraying the butts and lower limbs with azinphos-methyl 0.05 per cent when damage is seen is effective against these weevils.



Apple weevils damaging a citrus leaf.

Pittosporum longicorn *Strongylurus thoracicus*
Fig longicorn *Dihammus vastator*
Citrus branch borer *Uracanthus cryptophagus*
Citrus longicorn *Skeletodes tetrops*
Speckled longicorn *Paradisterna plumifera*

Importance and Distribution Several species of longicorn borers breed in a variety of native trees or shrubs and may infest citrus trees, where some cause twig or limb die-back. The larvae tunnel in the wood for many months, enlarge the tunnel as they grow, and finally pupate in a chamber hollowed out for the purpose. The adult emerges through the bark leaving an oval hole.

Longicorn borers are much more common in citrus on the coast than inland, perhaps because coastal orchards are more likely to be near native scrub. They are not of primary importance as they are attracted to trees already lacking in vigour for some other reason, such as old age, melanose, white louse scale infestation, shell-bark or root rot diseases, or scorching by fire.

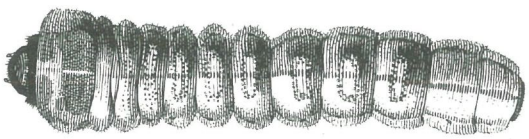


Fig longicorn larva. (Length, when fully developed, about 4 cm)

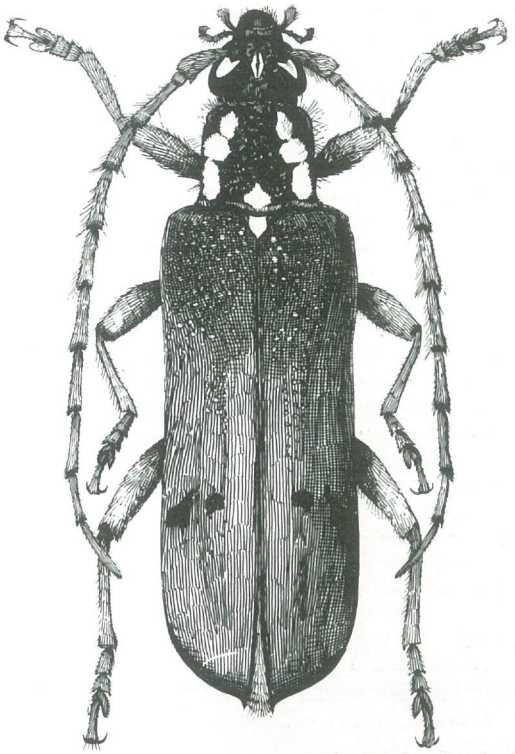
Conditions for Infestation Trees with die-back of wood and production of gum appear to be the most susceptible. Cut-back or skeleton-pruned trees are very susceptible. Some die-back is associated with the large pruning cuts and beetles are attracted to the dead stubs. Young and apparently healthy trees growing close to bushland are occasionally attacked.

Description and Life History All adult longicorn beetles have long tapering antennae that usually reach well beyond the end of the abdomen. The compound eyes are kidney-shaped, and each one partly surrounds the base of an antenna. The beetles fly actively, especially at night when they are often attracted to lights. The life histories are not well known, but the larvae of some species live for several years. The adults feed on bark and leave rectangular feeding marks, particularly on the dead or dying bark on which they lay their eggs. The larvae are yellowish, cylindrical and wrinkled, with a dark head and swollen thorax. Pupae are usually white and naked and show the outlines of the adult.

PITTOSPORUM LONGICORN commonly infests and causes die-back of twigs and small limbs of citrus on the Central Coast. It is particularly destructive to *Pittosporum* sp. and this is described by Froggatt (1923). The adult is 3 centimetres long, light brown and strikingly marked by a row of white spots on each side of the thorax. The larvae bore along the twigs and limbs, and sometimes leave openings through which sawdust-like material falls. They pupate in the wood in a chamber which is plugged at each end with fibre rather like wood-wool. The adults emerge mainly in November.

FIG LONGICORN sometimes attacks citrus trees in Central Coast districts. It usually infests the trunks or heavier limbs and the larvae bore deeply into the wood, so the damage affects the tree seriously.

The adult is yellow-grey, approximately 3 centimetres long, and has a prominent spine on each side of the thorax.



Pittosporum longicorn. (Length about 3 cm)

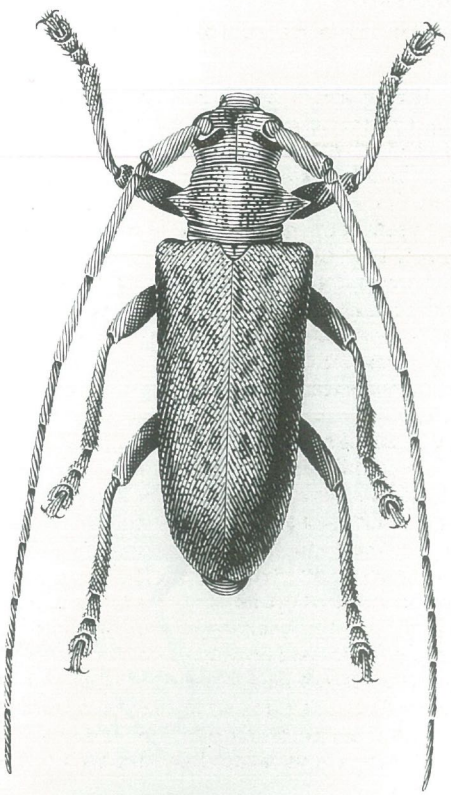
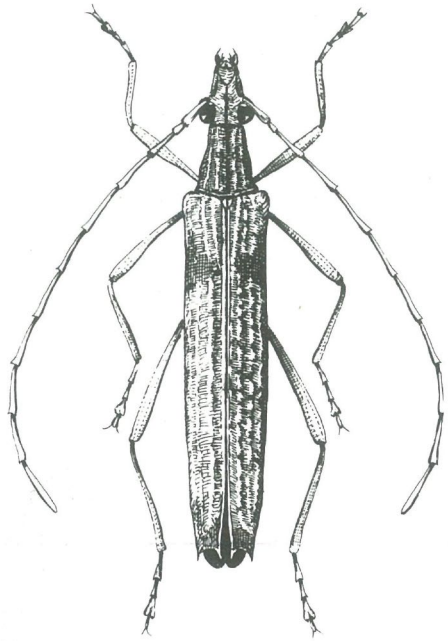


Fig longicorn. (Length about 3 cm)

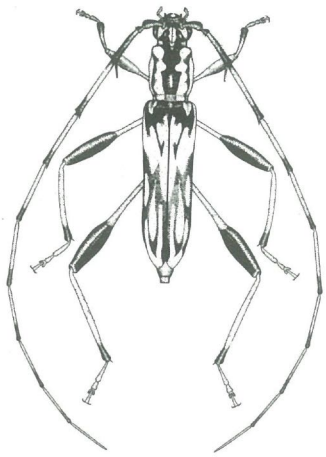
CITRUS BRANCH BORER has been recorded (Olliff, 1892) attacking cultivated citrus on the North Coast, where it infests the native finger lime, *Microcitrus australasica*. The adults are reddish brown, narrow, and up to 4 centimetres long. The larvae tunnel within the twigs and limbs sometimes for great distances.

CITRUS LONGICORN, sometimes called spider longicorn because of its long thin legs, is brownish grey and has a body about 12 millimetres long. The female lays eggs in dead bark, usually after one of the other borers has inflicted some damage. The larvae make shallow tunnels and these are packed with flour-like frass.

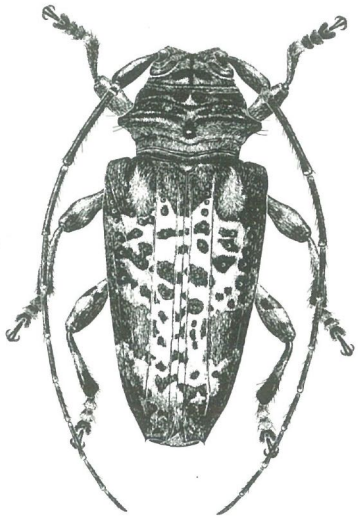
SPECKLED LONGICORN is about 12 millimetres long, light or dark grey, and speckled with brown marks. These beetles commonly feed and lay their eggs on melanose-affected dark-coloured bark below large stubs on pruned trees. The extrusion of gum seems particularly attractive to them. The larvae bore just under the bark and fill their tunnels with flour-like frass.



Citrus branch borer. (Length up to 4 cm)



Citrus longicorn. (Length about 12 mm)



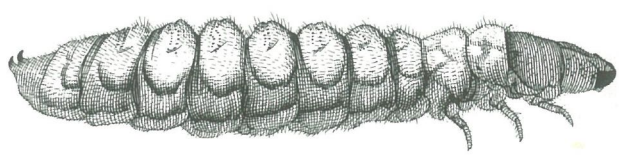
Speckled longicorn. (Length about 12 mm)

Control measures

NATURAL Wasp parasites attack longicorn larvae or pupae. Their papery cocoons are often seen in the tunnels. Predacious beetles of the family Cleridae also attack the borers.

APPLIED The accent should be on prevention of attack by maintaining tree vigour. Control is difficult after the grubs are in the wood and is mainly done by destroying them individually by pruning and cutting and probing tunnels with wire.

Where trees are skeleton-pruned to rejuvenate them, special care is needed to avoid failure from many causes, including longicorn borer infestation. Rejuvenation should not be attempted unless the trees are sound in roots and butts, and the trees should be well fertilized in the autumn before pruning in the spring. After pruning, the framework of the trees should be thoroughly sprayed with lime-sulphur to control white louse scale, and after this at the appropriate times, a programme of Bordeaux mixture sprays should be carried out for melanose control. All prunings should be burned as soon as possible. All pruning cuts should be made well below dead or dying wood; the cuts should be as clean as possible and sloped to shed rain. Dead and dying bark should be scraped or rasped from the trunks, and the margins of the affected area cut back to expose healthy wood. All large cuts and exposed tissue should be painted as soon as possible with a waterproof paint containing a fungicide and an insecticide. The following treatment has been found to be effective: first the cut and exposed surfaces are washed with a solution of permanganate of potash, and then painted with a mixture of DDT and copper oxychloride wettable powders in plastic house paint thinned with water to a free-flowing liquid.



Predacious larva of a clerid beetle. (Length, when fully developed, about 2.5 cm)

Monolepta beetle *Monolepta australis*

These small beetles are very strong fliers. They sometimes swarm in enormous numbers on citrus and on many other crops or ornamental trees, in spring and summer in the North Coast districts. In spite of long experience of raids by this pest, its life history and natural breeding material are unknown.

A swarm of the beetles seems to appear from nowhere and quickly ruins the blossoms, buds and young foliage of a citrus tree in spring, or causes considerable damage to leaves in summer. The whole plant may look scorched and, while this may happen to some trees, others nearby may hardly be touched.

The beetles are about 6 millimetres long, and yellow with red marking on each wing cover – at the base and in a small spot in the middle.

Control measures An attack, if detected quickly, may be dealt with effectively by lightly spraying the buds, blossoms and young growth with carbaryl 0.1 per cent.

Pitted apple beetle *Geloptera porosa*

These small beetles occasionally damage trees in coastal districts in early summer. They chew holes in leaves and in green bark. The beetles are about 6 millimetres long, red-brown and the surfaces of the head, thorax and wing covers are densely pitted. Like the monolepta beetle they may appear unexpectedly and, when observed, may be dealt with by similar sprays.

More details on this insect may be found on page 102 under Apple Pests.

THYSANOPTERA

Greenhouse thrips *Heliothrips haemorrhoidalis*

Importance and Distribution This is a pest of many plants around the world. It thrives in tropical and sub-tropical conditions as well as in greenhouses. In New South Wales, infestation is sometimes fairly important in coastal citrus orchards when mature late-hanging Valencia oranges are attacked.

Conditions for Infestation Thickly-foliaged trees, with clustered fruits allowed to hang until late summer in seasons of good summer rainfall, provide suitable conditions for this thrips. Infestation may be expected in shaded situations protected from wind.

Plants attacked The host range of the greenhouse thrips is extensive and includes many garden shrubs and trees. Valencia is the only variety of citrus that suffers much damage. Other varieties do not have fruit in a susceptible state when the thrips are numerous.

Description and Life History The development stages of the greenhouse thrips are egg, nymph (two stages), prepupa, pupa and adult. The adult is black, about 1.5 millimetres long, with narrow fringed wings. The wings, legs and antennae are whitish. There are no males. All adults can lay the white kidney-shaped eggs, 0.3 millimetres long, that are inserted singly into leaf or fruit tissue just under the surface. The eggs swell as they develop and cause minute lumps or pimples to appear on the infested surface.

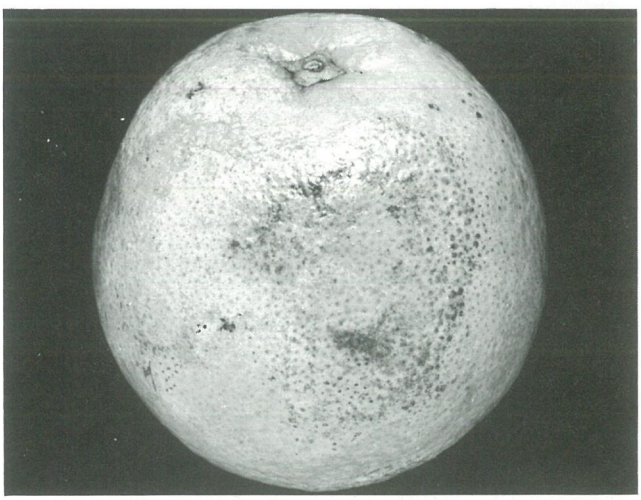
The newly-hatched nymph is about 0.5 millimetres long and white, changing to pale yellow, with red eyes. The two nymphal stages carry a drop of liquid excrement on the tip of the abdomen. The prepupa shows wing pads that become longer in the pupal stage. The prepupa and pupa do not feed.

The adults lay one or two eggs per day and live for up to three months. The incubation period for the eggs may last from seven to twenty days under most favourable conditions, while the complete life cycle may extend over 33 to 38 days.

Injury Greenhouse thrips on citrus feed only on ripe or almost ripe fruit, or on mature leaves where two surfaces (leaf or fruit) have been in contact, or under spider webbing. They pierce the surface cells and the attack produces ash grey patches on the rind which are sprinkled with black spots of excreta. The rind also becomes flaccid after harvest.

The thrips causes considerable damage to the leaves of some trees, but on citrus it is important only because it blemishes the fruit and reduces its shelf life.

Dispersal The adults have only been seen to fly for a few centimetres. Some adults may be wind-borne under some conditions, but this would be unusual as they prefer shady and quiet situations. They are probably transported sometimes by wind on shrivelled leaves. Visiting insects probably transport some thrips.



Greenhouse thrips damage.

Control measures

NATURAL A tiny wasp, *Ceranisus* sp., has been found abundantly on garden plant hosts of *Heliothrips* in New South Wales coastal districts, and it has been noted that the thrips were scarce in years following those in which this parasite was numerous.

APPLIED Maldison 0.05 per cent spray is effective in controlling the pest.

Citrus rust thrips *Chaetanaphothrips orchidii*

Importance and Distribution To date this insect has been important in New South Wales only in limited areas of low-lying orchards in the Wyong and Windsor districts. It has been given the name 'orchid thrips' in Florida (Ebeling, 1950). Thompson (1939, 1940) discussed the insect and its damage to citrus in Florida. It occurs as a pest of many plants in glasshouses in Europe but has only been recorded in New South Wales on citrus. The thrips was first seen here at Wyong in 1962, but apparently identical damage had been seen earlier at Ourimbah.

Description and Life History Citrus rust thrips, which are very similar to banana rust thrips, *C. signipennis*, are very active and golden yellow with black markings on the narrow fringed wings. They move rapidly into sheltered positions when disturbed and exposed to light. Eggs are laid in the tissues of the host. The full-fed nymphs go into the soil to pupate.

Injury Feeding injury occurs on the fruit surface in summer–autumn, at contact points between young fruits and young fruits and leaves, causing brown blemishes which become slightly raised and lead-coloured with the increasing maturity of the fruit.

Citrus rust thrips blemish. (See also page 79.)

Control measures Natural controlling agents for this insect are not known.

Maldison 0.05 per cent spray is suggested if thrips are present. Spraying should be done when the young green fruit begin to touch in clusters, in summer, and repeated at intervals of a few weeks.

Plague thrips *Thrips imaginis*

Citrus blossoms are commonly infested in spring by huge numbers of thrips feeding on the petals, pistil and developing ovary. Some petal-browning occurs, and egg-laying in the pistils causes small blisters. This injury, even when quite extensive, seems to cause no harm. There is no evidence that it affects the setting of the crop.

The pest is discussed in more detail on page 102 under Apple Pests.

Onion thrips *Thrips tabaci*

On only a few occasions has skin blemish been seen on ripe oranges at Gosford which was thought to have been caused by onion thrips damage shortly after fruit set. The affected trees were always immediately adjacent to old pea crops that had been heavily infested by this thrips and had hayed-off as the citrus fruit was setting. The injury occurred only on trees with peas growing between them or a row or two away. The blemishes were oval silvered areas at the pistil end.

More details are given on page 272 under Onion Pests.

HEMIPTERA

Scale insects

These are the most important pests of citrus. They can be present in huge numbers and can blemish the fruit and be seriously harmful to the trees. Although soft-bodied, they have strong protective coverings. Feeding is by piercing and sucking mouthparts, which are fine flexible spear-like components held together as a feeding tube. Scale insects have only a limited ability to move, and as adults are usually immobile.

Scale insect pests of citrus are either armoured scales (family Diaspididae) or soft scales (families Coccidae and Monophlebidae).

Armoured scales

These are small, flattened and soft-bodied insects that have hard protective covers, for example, California red scale and purple scale. Several generations can be produced per year and they can build up rapidly to high populations. Their presence is a blemish on fruit, and their feeding causes fruit-marking, leaf-fall and sometimes twig and branch die-back. They feed on the contents of plant cells through a long fine rostralis. Saliva injected while feeding by some species is toxic to plant cells. Armoured scales do not produce honeydew, and are not attended by ants.

Armoured scales can cause leaf-fall and die-back: young orange tree severely damaged by California red scale.

Armoured scales are a blemish on fruit: California red scale on orange (above) and purple scale on orange (below).

The body of the insect under the scale cover is soft. The head and thorax are combined, and most of the abdominal segments are fused to form the pygidium which has a fringe of plates, lobes and setae. The insect secretes waxy threads from pores on the pygidium and shapes them into a ribbon with the pygidial fringe. The ribbon is used to build the protective cover over the scale, and is placed in position by movement of the insect. Round scales rotate to form their covers; elongated scales move from side to side.

Some armoured scale females deposit their young beneath them as eggs. In other species, the eggs hatch within the body of the female. The larvae emerge from beneath the adults as tiny flattened six-legged 'crawlers' which are able to move actively. They may either settle quickly, or wander about on the tree for several days, or be carried by wind, birds, insects or man to other trees. During this period they are influenced by their characteristic responses to light, gravity, heat and contacting surfaces. After the crawler has settled and inserted its feeding tube, the rostralis, it starts to produce the scale cover.

Female armoured scales have two larval stages and an adult stage; males have two larval stages and prepupal, pupal and adult stages. The male can be distinguished from the female after the first larval stage as the male is more elongate. The young scale moults when developing to the next stage, and during moulting the scale cover adheres firmly to the insect. The legs are lost at the first moult. Formation of the scale cover continues after each moult. The covers of the earlier stages remain as clearly distinguishable parts of the final cover, and are called 'exuviae'. This is explained by Dekle (1965).

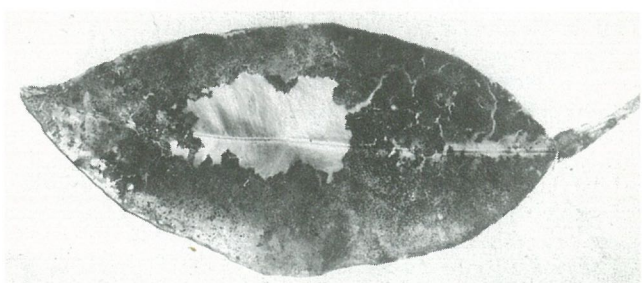
The adult female is wingless and remains under the scale cover. It is fertilized there by the adult male – a delicate two-winged insect which flies weakly, has no mouthparts and lives for only a very short time.

Soft scales

They are larger than armoured scales, and examples are black scale and the wax scales. They have no separate protective covering and are soft-bodied, but in adults the upper surface is usually tough, or protected with waxy or mealy secretion. The insects have only one or two generations per year.

Soft scales feed from the larger plant vessels of midribs and stems and do little direct damage. The harm they do results from their copious secretion of honeydew, a liquid rich in sugars. Sooty mould fungi (group Capnodiales) grow profusely on this and encrust the trees in black, thus interfering with photosynthesis. It also makes the fruit dirty, but this is largely overcome by modern methods of cleaning fruit before packing.

A soft scale, Chinese wax scale.



Sooty moulds grow on honeydew from soft scales.

The honeydew of some soft scales, for example soft brown scale, is very attractive to ants, and they attend these scales in large numbers to remove the honeydew and sometimes to move the young scales. Their activities interfere significantly with those of the insect enemies of the scales.

The young of soft scales are deposited as eggs under the adult female, and usually accumulate there in very great numbers before hatching. The larvae are tiny flat active six-legged 'crawlers'; they emerge from beneath the parent scale and move out on to foliage or green twigs to settle and feed. Usually they move back later and settle on twig growth where they continue to feed and develop.

Soft scales do not lose their legs after the first larval stage and many can crawl in all stages, although some are sessile as adult females. Females have two larval stages, then become wingless adults. Males have two larval stages, and prepupal and pupal stages, before becoming winged adults. In some soft scales, for example white wax scale, reproduction is parthenogenetic. In others, for example black scale, males are known but are not often seen.

Dissemination of scale infestations

Scale insects are usually brought into the orchard at planting. Disinfestation of young trees before planting out, by dipping the trunk and foliage in a suitable scalicide, can postpone the need for scale control spraying for several years.

Nursery trees are likely to carry scales, as infestation in nursery rows is spread readily by young scales crawling from tree to tree or being moved on the clothing of orchard workers. Propagation wood and buds should be taken only from trees that are free from scale; nursery beds should be isolated from citrus or other trees with citrus scales, and staff should change their clothing before entering nursery rows after working in infested areas.

In the orchard, infestation is spread by wind, by visiting birds and insects, and on the clothing of orchard workers during harvesting.

Scale crawlers and infested leaves may be carried by wind for considerable distances. Quayle (1916) found crawlers of black scale wind-borne for up to 137 metres, and of California red scale carried for 45 metres. First-stage white wax scale crawlers were found to be wind-borne over at least 30 metres, and second-stage crawlers over 12 metres (Hely, 1960).

In the Murrumbidgee Irrigation Area native zebra finches nest in thick leafy citrus trees, and the California red scale infestations around the nests indicate that the birds carry the scale.

It is likely that visiting insects, such as ladybirds, accidentally carry scale crawlers. Ants carry young soft scales, notably soft brown scale.

Natural control factors

Citrus trees provide an almost permanent source of food and shelter for many insects and mites. Some harm the tree – directly or indirectly – some are unimportant, some are predatory on a number of insects or mites, and some are parasites of particular insects, especially scales. Ladybird larvae and adults, lacewing larvae, and several caterpillars are predators on scale insects, and minute wasps – both native and introduced species – parasitize scales. There are fungi which grow on dead and sometimes on living scales.

The association of insects and mites on the trees usually maintains itself in a fairly stable state, but occasionally there may be damaging increases in certain pest species. Unfavourable changes in this balance are often initiated by artificial intervention, such as destroying natural enemy insects by unsuitable use of an insecticide, or spraying with strong Bordeaux mixture fungicide, which repels valuable predators.

Insecticides applied at the wrong time have caused striking increases in white wax scale populations. In experiments at Kulnura near Gosford, between 1953 and 1955, gross infestations of white wax scale followed spring applications of maldison or parathion (Hely and Gellatley, 1962). It was concluded that the insecticides had been ineffective against the scales at this time, when they were adults containing eggs, but instead had eliminated predatory ladybirds from the trees shortly before the emergence of the crawler scales. The same insecticides controlled white wax scale when applied in January to crawler scales on the foliage.

Spraying with Bordeaux mixture has been followed by increases in populations of white wax scale. This was shown by an experiment at Gosford in 1937–38. Bordeaux mixture was applied to large Valencia trees in spring at petal-fall, and again in December. In the following December, counts showed fourteen times more scale larvae on the leaves of sprayed than on those of unsprayed trees (Hely, unpublished data). It is considered that the cause is the persistent residue left on the foliage by the Bordeaux spray. The steel blue ladybird, an important predator of white wax scale young stages, does not colonize citrus trees carrying heavy deposits of this residue.

Excessive road dust on the trees and excessive cultivation or heavy stocking of the orchard with poultry can result in an upsurge in numbers of armoured scales, particularly California red scale. Bodenheimer (1951) describes this effect in Israeli orchards subjected to heavy dust raised by the activities of a cavalry camp. In New South Wales, the tar sealing of roads beside citrus orchards has been followed by dramatic reductions in California red scale populations on the trees, without any additional control treatments. This stimulating effect of inert dust on armoured scales has been ascribed to the dust helping the young crawler scale to anchor itself on the leaf during the insertion of its feeding tube. It is also due to unfavourable effects of the dust on natural enemy insect activity.

Ant activity on trees is very important in regard to some soft scale infestations. The ants disturb the attacks of parasites. Ant control can cause rapid reduction in soft scale numbers.

Weather variations affect citrus scale insects very significantly. For example, hot dry weather favours California red scale increase, but white wax scale is readily killed by very hot summer weather. The effects of weather may be direct or may be indirect through effects on natural enemy insects.

Biological control of citrus scale insects

The introduction of specific natural enemies to fight introduced scale insect pests had its first spectacular success in California in 1888. Cottony cushion scale had arrived from Australia about twenty years earlier and, without its native natural enemies, had multiplied so rapidly that it seriously threatened the continued existence of the Californian citrus industry. A colony of vedalia ladybird, *Rodolia cardinalis* (Mulsant), from Australia was liberated in a heavily infested citrus orchard. Spectacular control of the scale in Californian orchards followed within eighteen months (Ebeling, 1950).

A great deal of work has been done, by Californian entomologists particularly, in searching the world for natural enemies of scale insects, especially California red scale. Several *Aphytis* spp. wasps are valuable parasites of armoured scales (DeBach, 1969),

and have been introduced to many countries. In New South Wales, *A. chrysomphali* (Mercet), *A. melinus* DeBach and *Comperiella bifasciata* Howard are effective introduced parasites of red scale.

Parasite emergence holes in California red scale.

Exact understanding of early introductions of parasites is difficult, due to deficiencies at the time in the taxonomy of both parasites and scale insects, and particularly in differentiation between *Aonidiella* spp. In 1905, G. Compere brought *Aphytis* parasites of California red scale from China to Western Australia, where they established themselves successfully (H. Compere, 1961). This was probably the occasion on which *A. chrysomphali* was introduced to Australia. Parasites from Western Australia were established in New South Wales in 1925–26 (Wilson, 1960), where they have been active against California red and yellow scales in coastal districts for a long time, and Gosford was the source from which *A. chrysomphali* was established at Mildura, Victoria, in 1954. In the late 1960s *A. chrysomphali* became a common parasite of California red scale in many areas around Mildura (McLaren, 1971), and it was found frequently in California red scale in the Murrumbidgee Irrigation Area.

Aphytis melinus from Pakistan (DeBach, 1959) was imported from California to Mildura in 1961 (McLaren, 1971), and has proved to be a valuable parasite of California red scale. It was established in the Murrumbidgee Irrigation Area, from Mildura, in 1972 (Anon, 1974). It has been reared commercially in South Australia and supplied to some Murrumbidgee Irrigation Area and mid-Murray River district orchards.

Comperiella bifasciata was taken in to California from Japan in 1924–25 and proved to be a race parasitizing yellow scale; introduced from China in 1940, it was a race parasitizing California red scale (Smith, 1942). In 1942, and again in 1947–49, the Chinese race was imported from California to Australia (Wilson, 1960). Since the late 1960s it has occurred very commonly in California red scale in the Murrumbidgee Irrigation Area and the mid-Murray River district, and commonly in coastal districts. *C. bifasciata* brought yellow scale under biological control around Mildura (McLaren and Buchanan, 1973). It is not known whether *C. bifasciata* parasitizing California red scale and yellow scale in Australia are separate races. There is no record of successful introduction of the Japanese race.

Natural enemies of white wax scale were sought in Africa by Gurney (1936), but the two wasp parasites released in New South Wales failed to establish themselves on white wax scale. More recently, Snowball (1968) studied parasites of white wax scale in South Africa. Subsequently he made introductions which resulted in the establishment in Australia of two wasp parasites, *Anicetus communis* Annecke and *Paraceraptrocerus nyasicus* (Compere), on white wax scale.

There are many other introduced parasites of scale insects in New South Wales. While some have been introduced deliberately, many others probably came with scale insects on early imports of citrus planting material.

Integrated control of citrus scale insects

The term 'integrated control' has many interpretations, but its use in this book refers mainly to the use of insecticide in a way which will not upset the insect balance on the trees sufficiently to cause a serious upsurge in pest numbers (Rosen, 1967; Bedford, 1968; Annecke, 1969). This has been generally achieved on citrus in New South Wales by the correct use of recommended insecticides which, with a few exceptions, have not caused major increases in pest problems. In relation to the world scene regarding integrated control of insect pests of citrus, it should be remembered that Australia does not have the *Scirtothrips* spp. thrips pests of California and South Africa. The latter are serious pests which blemish young fruits and require insecticide control early in the season which may be very detrimental to natural enemy insects.

Another view of integrated control is taking advantage of the natural factors contributing to control, such as parasites and predators and weather effects, before intervening with insecticide application (Flaherty *et al*, 1973). Practical systems for the quantitative assessment of pest, parasite and predator activity will be required if decisions are to be made on the need for applying insecticide in individual orchards. Meanwhile, the parasitic and predatory natural enemy insects can be encouraged to contribute more successfully to scale insect control in the orchard by minimizing the use of sprays which are toxic or repellent to them – oil sprays are likely to be the least harmful – by reducing dust disturbance in the orchard, and by controlling ants, especially where black scale or soft brown scale infestations are present.

ARMOURED SCALES

The general characteristics of armoured scales are discussed on page 44.

California red scale *Aonidiella aurantii*

Importance and Distribution This scale, which was first described in 1878 from specimens on Australian citrus fruit imported into New Zealand, originated in South East Asia. It is now distributed throughout the citrus areas of the world and is the principal citrus pest in California, South Africa and Australia. In New South Wales, it is important in all inland citrus

areas, primarily as a blemish on fruit, although it can damage trees severely. In coastal districts it was once significant and is now a problem only occasionally.

Conditions for Infestation Abundant light and a deposit of dust on the plant provide optimum conditions. California red scale is a pest of warm dry environments, but good rain in autumn after a dry summer often leads to spectacular increases. It thrives on mature fruits, so the common orchard management practice of allowing mature Valencia oranges to remain on the trees for long periods favours red scale increase on those trees.

Plants attacked There are many hosts, for example, olive, fig, pear, grape, rose, Bathurst burr, *Xanthium spinosum*, and fat hen, *Chenopodium album*. Lemons are the preferred citrus host, but all citrus varieties may be attacked.

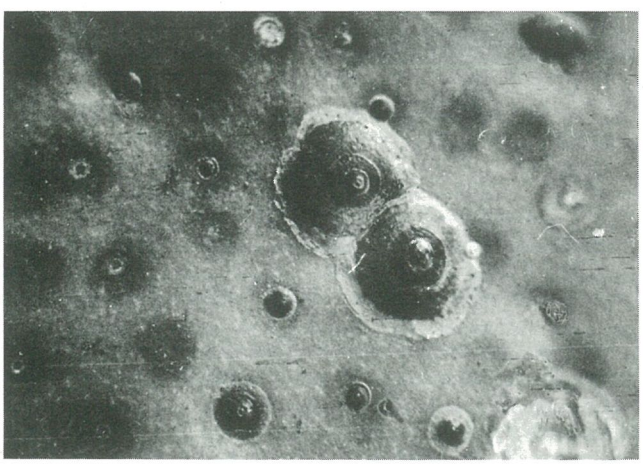
Description and Life History California red scale is a typical armoured scale. The cover of the adult female is approximately 2.5 millimetres in diameter and circular in outline, with the centre slightly raised. It is parchment-like, grey and semi-transparent so the insect's yellow body colour makes the whole look red or reddish brown. The male scale cover is elongate, and smaller and paler than that of the female. The adult winged males are light orange-yellow.

There are no eggs. The larvae are light yellow, oval, less than 0.5 millimetre long and six-legged. They move out from under the female scale and crawl about for a period usually of a few hours, then settle permanently. Soon after settling they secrete a white covering and become 'white caps'. Mortality among crawlers is high; as many as 40 to 50 per cent may die in summer and many more in winter.

After the first moult, the more elongate covers of the males can be distinguished from the round covers of the females.

After the second moult, the body of the female does not fill the area under the cover initially. Fertilization by the male takes place at this 'grey adult' stage. The virgin female attracts the male by producing a pheromone (Tashiro and Chambers, 1967); this discovery was used by Shaw and Moreno (1971) to develop a male lure trap as an efficient California red scale detector.

After fertilization the pygidium retracts between the thoracic lobes so that the female becomes kidney-shaped (Tashiro and Moffitt, 1968). Extension of the cover ceases and the insect then fills the space under it. The cover appears to be all red, and it adheres firmly to the body of the insect. Production of young then begins at the rate of a few larvae per day.



California red scales – close-up.

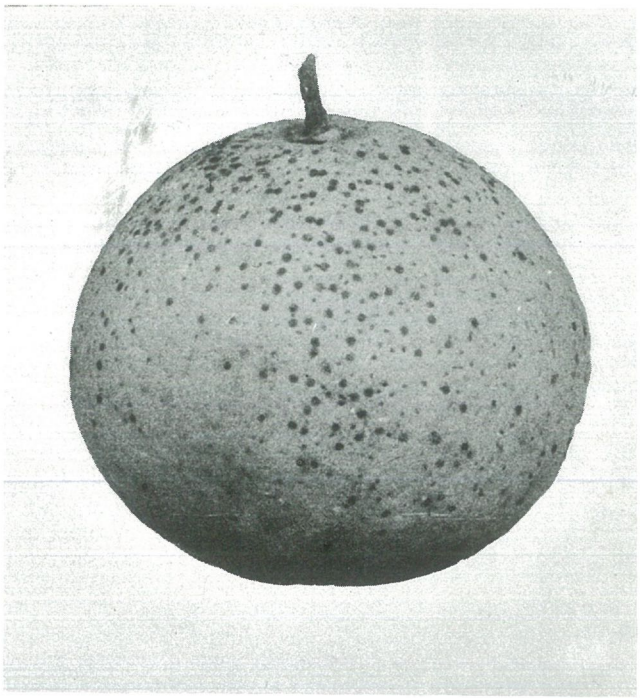
Ward and Johnston (1937) made life-history studies on California red scale in Victoria and recorded the following data:

Establishment to first moult	12 to 23 days, average 16
Establishment to end of second moult	29 to 40 days, average 35
Establishment to reproduction	63 to 80 days, average 69

Males were produced after an average of 38 days. Reproduction by females went on for up to 60 days, with as many as 145 larvae being produced per female. In these studies, no larvae were produced between May and November. In the warmer conditions prevalent in most of New South Wales, the birth of larvae goes on in winter at a slow rate.

Injury California red scale attacks all above-ground parts of the tree. It injects a toxic saliva as it feeds and, because of its large numbers, can cause extensive injury in a short time. This is manifested as blemished fruit, leaf yellowing, leaf-fall, restriction in fruit growth followed by splitting and fruit-fall, hardening of bark which may be followed by splitting, and die-back of twigs and branches. Young trees may be killed and older trees may lose large branches. With appropriate control measures and the beneficial effects of natural enemies, the main injury is usually only fruit-blemishing.

California red scale on citrus twigs.



California red scale is a severe blemish on grapefruit.

Die-back of mature orange tree caused by severe infestation of California red scale.

Dispersal Most orchard infestations originate from planting infested trees. Infested buds or grafts can carry the scales to new trees in nurseries. Within the orchard the pest is spread by wind (Willard (1974) recorded crawlers being wind-borne for 312 metres), by visiting birds and insects, and on the clothing of orchard workers. Birds, such as zebra finches, commonly nest in citrus trees in inland districts and are probably responsible for much transport of larval scales from tree to tree.

Control measures

NATURAL Many natural factors help to reduce scale numbers. These include weather, insect predators and parasites.

WEATHER Very hot weather conditions will kill red scale. The record heat wave of January 1939, with a maximum shade temperature of 48°C, caused widespread heavy mortality of red scale in Murrumbidgee Irrigation Area orchards. Martin and Black (1960) used infested orange fruits to investigate heat mortality and achieved reliable 100 per cent kills after 2.25 hours of exposure to 50°C, and there was little or no damage to the fruit.

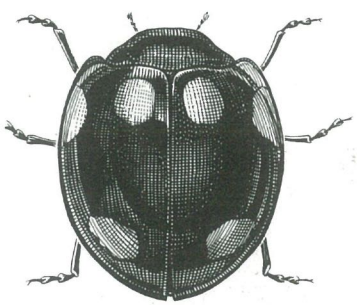
Low temperatures in winter in the citrus areas have little effect in limiting red scale. Heavy infestations have followed unusually cold winters.

Rainfall has an influence. In coastal districts, wet seasons do not suit red scale but favour the entomogenous red-headed fungus, *Fusarium coccophilum* (Desmaziere) Wollenweber and Reinking, which seems to attack mainly weakened scales. In inland districts, abundant autumn rain after a dry summer favours red scale.

INSECT PREDATORS AND PARASITES California red scale has many predatory and parasitic insect enemies. In coastal orchards, on mature trees, they usually prevent red scale numbers developing to problem levels, and in inland orchards they can reduce red scale problems significantly.

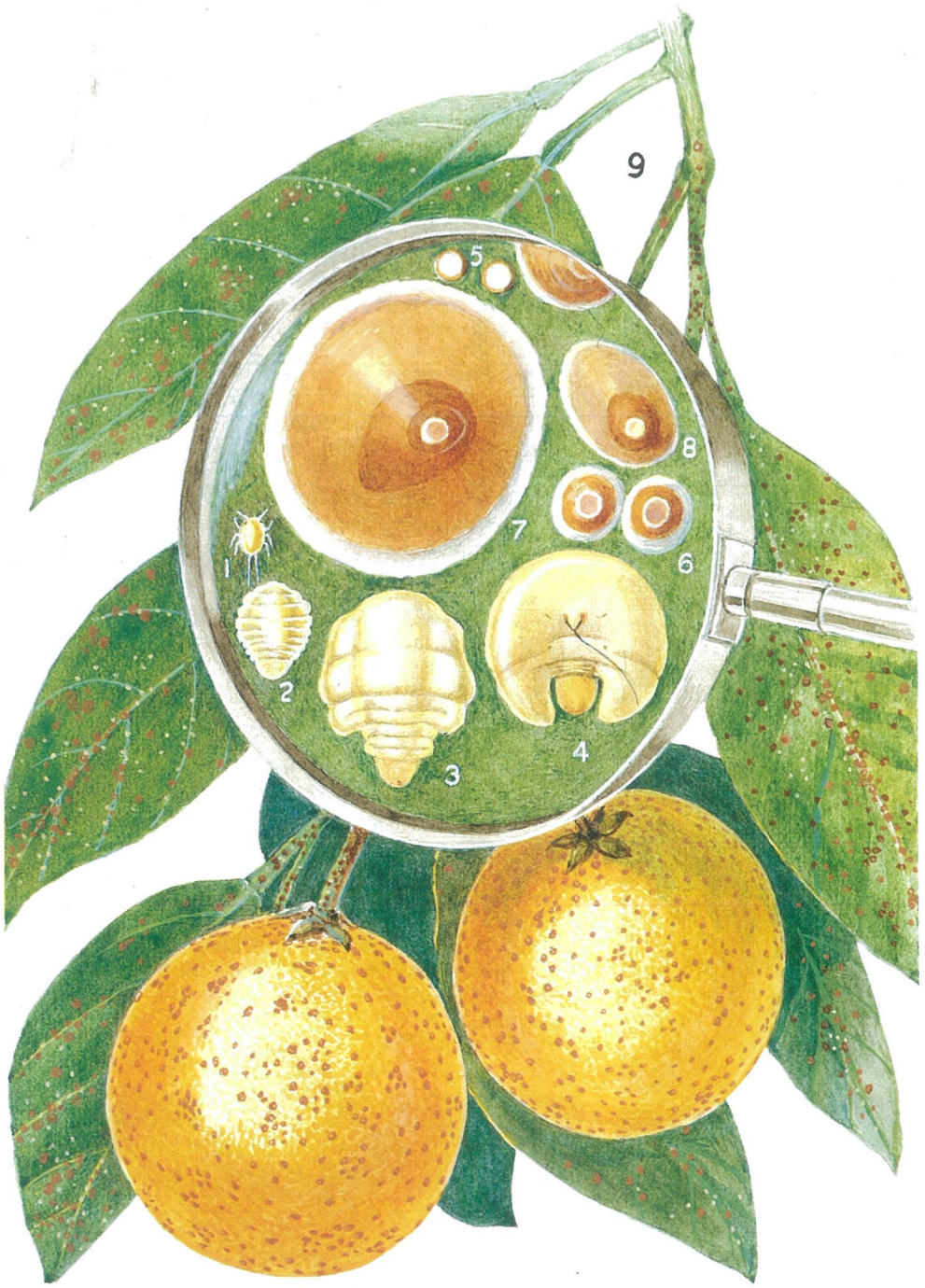
The predators are the larvae and adults of ladybirds, lacewing larvae and some predatory caterpillars. In inland areas the most important is the scale-eating ladybird, *Lindorus lophantae* Blaisdell. The adult is about 3 millimetres long, and black with a fine grey pubescence. The larvae are slate grey. The ladybird is seen commonly in autumn and feeds actively on into winter.

On the coast the steel blue ladybird, *Halmus chalybeus* (Boisduval) is a useful predator and attacks many different scales. The adult is 3 to 4 millimetres long; the male is blue and the female green. The larva is yellow-grey. This species is active from late spring to early autumn and overwinters as an adult. It does not thrive in inland areas, and in very hot dry conditions in coastal districts the adults move to the base of the tree or seek shade outside the orchard. Another ladybird *Orcus australasiae* (Boisduval) occurs commonly in coastal districts, and sometimes in mild wet conditions in inland areas. The adults are about 5 millimetres long and dark blue with yellow blotches, and the larvae are black and yellow. It is a much less effective predator of red scale than the steel blue ladybird.



Orcus australasiae, a ladybird predator of California red scale and other scale insects. (Length about 5 mm)

Larvae of green lacewings, *Chrysopa* spp., insert their curved jaws under the scales and prize them loose. After consuming the body contents, the larva carries the scale cover on its own back until it eventually becomes covered with these scale remains. The adult female attaches her eggs by long slender stalks to foliage and fruit.

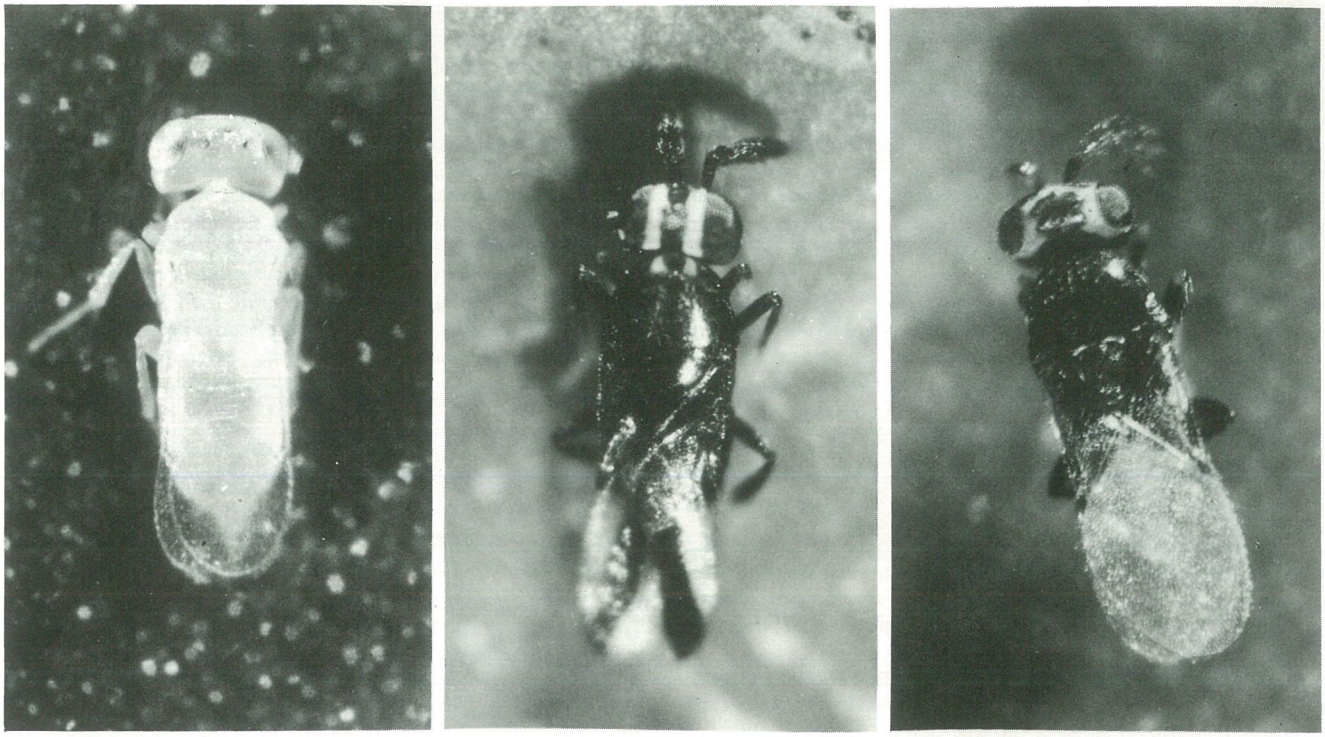


California red scale
Aonidiella aurantii

1 First-stage larva or crawler; **2** second-stage female; **3** early adult female; **4** old adult female; **5** scale covering of larva or 'white cap' stage; **6** scale covering after first moult; **7** scale covering of adult female; **8** scale covering of male; all enlarged twenty-two times. **9** Citrus foliage and fruit infested with scales; actual size.

The larvae of a moth, *Batrachedra* sp., are sometimes found feeding on California red scale under a fine white webbing, but only in heavy infestations of the scale.

Parasites are more important than predators in the natural control of red scale. The main species are the tiny introduced wasps *Aphytis chrysomphali*, *A. melinus* and *Comperiella bifasciata*. Adult *Aphytis chrysomphali* are readily seen running about rapidly over colonies of California red scale and yellow scale in coastal districts in autumn. They are yellow winged wasps about 0.8 millimetre long. The female deposits the egg under the scale covering, on or under the scale body, and the wasp larva feeds externally on the scale insect. The adult wasp emerges from under the edge of the scale cover or through an exit hole that it cuts in the cover. Adult wasps also kill scales by puncturing them and sucking the juice. *A. melinus* is very similar in appearance to *A. chrysomphali*. Quednau (1964) developed a key for the identification of *Aphytis* species which used pupal as well as adult characteristics.



Parasites of California red scale: *Aphytis* sp. at left (length about 0.8 mm); *Comperiella bifasciata* — female centre, male at right (length about 1.2 mm).

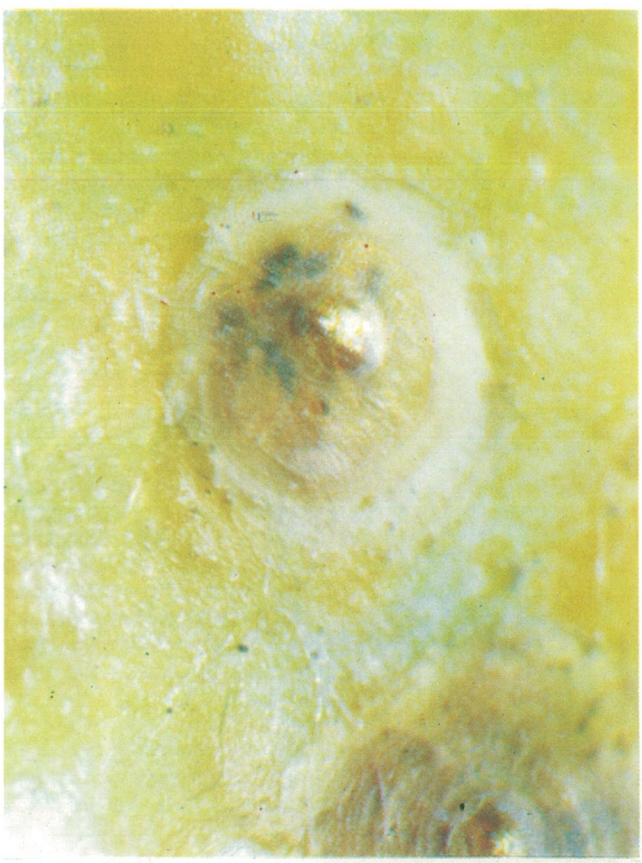
Comperiella bifasciata is a dark-coloured winged wasp about 1.2 millimetres long. The female is marked with white on the head, has two dark stripes on each forewing, and carries the apical part of these wings semi-erect. Liberations of the wasp were made in the Murrumbidgee Irrigation Area in the 1940s but it did not become common there until over twenty years later.

APPLIED Control of California red scale by spraying usually requires very thorough application so that all parts of the tree are wetted. A very high percentage kill should be the objective. There may be millions of scales on the tree and the potential for rapid increase from survivors is high.

Proper timing of control treatments is important and has been demonstrated in a number of experiments in New South Wales (Hely, 1940; Hely and Wason, 1945). Mid-February is a suitable time for a single control treatment, as an ample fruit size increase follows which will aid the shedding of scales killed on the fruit, and the autumn weather is not warm for long enough to enable the scale population to recover significantly.

Treatment in February only is not sufficient for heavily infested trees, as scales will have caused fruit-pitting on these trees by February. Control treatment is required at about the end of November, and again in about mid-February. The November treatment is to check the infestation when it is beginning to increase after winter, and so reduce the settling of scales on the fruit early in the season. It need be only an outside cover spray of the tree canopy with petroleum oil at 1.25 per cent – a treatment rate which is normally too low for good efficacy. The February treatment is more important, and a very effective material must be applied thoroughly, wetting all parts of the tree.

Many evaluations have been made of petroleum oil, organophosphorus insecticide and organophosphorus insecticide-



Parasitized California red scale.

petroleum oil combination sprays for red scale control. Petroleum oil emulsion at 2 per cent dilution is an effective treatment, but it does tend to impair fruit quality and reduce blossom and for these reasons it is unsuitable for use more than once per season. A number of organophosphorus insecticides, for example azinphos-methyl, carbophenothion, dimethoate, ethion, maldison and methidathion, has been very effective at reasonably economic dilution rates, especially in mixture with petroleum oil at 1 per cent. Ethion is available in a convenient formulation in petroleum oil. Methidathion used without petroleum oil proved to be very effective. Azinphos-methyl and methidathion are more toxic to the user than most other insecticides commonly used on citrus. The current recommended control measures are summarized below.

LIGHT INFESTATIONS Spray thoroughly in mid-February with petroleum oil emulsion 2 per cent, or ethion 0.075 per cent-in-petroleum oil 1.25 per cent, or maldison 0.1 per cent plus petroleum oil 1 per cent, or methidathion 0.05 per cent. Ethion-in-oil is also effective against citrus rust mite which is an advantage in north-western inland citrus areas.

If Bordeaux mixture fungicide spraying is needed at the same time as red scale control treatment, such as in coastal orchards, petroleum oil and ethion-in-oil are compatible with Bordeaux at strengths up to 250 grams bluestone-250 grams lime-100 litres water.

HEAVY INFESTATIONS A two-spray programme should be used. In late November, apply petroleum oil emulsion 1.25 per cent as an outside cover spray of the tree canopy. In mid-February, apply ethion 0.06 per cent-in-petroleum oil 1 per cent, maldison 0.1 per cent plus petroleum oil 1 per cent, or methidathion 0.05 per cent.

The November treatment could be an organophosphorus insecticide-petroleum oil 1 per cent mixture spray if the insecticide is required against other pests, for example azinphos-methyl 0.05 per cent against light-brown apple moth or maldison 0.075 per cent against katydids.

Where natural enemy insects are operating usefully in the orchard, petroleum oil sprays will be less harmful to them than organophosphorus insecticides.

Control of red scale is compulsory, under the *Plant Diseases Act*, in New South Wales.

Yellow scale *Aonidiella citrina*

Yellow scale was often confused with California red scale, despite differences in habit and ecology, until McKenzie (1937, 1956) demonstrated microscopic morphological differences. Infestations in the orchard can be distinguished by colour and habit. Yellow scales are paler and flatter; they commonly infest leaves and fruit, but only occasionally the green twigs and seldom the older wood. Yellow scale is usually only on the lower and inner parts of the tree, and commonly occurs on the lower surfaces of the leaves. Whereas red scale thrives in warm dry well-lighted situations, yellow scale thrives in more temperate and humid shady conditions. In some situations, old trees have been infested with yellow scale and younger trees nearby with red scale. Yellow scale occurs commonly in coastal areas and in the Lower Murray district. It has not been recorded in the Murrumbidgee Irrigation Area.

Yellow scale does less damage to the tree than California red scale, and is a less obvious blemish on mature fruit.

The host range is wide but, apart from citrus, it is generally found on garden shrubs, ivy and privet.

Control measures Natural enemies of red and yellow scales are generally similar, but the conditions most suitable to yellow scale also suit its parasites. On the coast, *Aphytis chrysomphali* is important in limiting yellow scale increase. *Comperiella bifasciata* is a common and valuable parasite for control in Lower Murray districts.

If direct control measures are required, the treatments recommended for California red scale are effective. Spray application must be thorough to contact scales on the undersides of lower and inner foliage.

Purple scale, mussel scale *Lepidosaphes beckii*

Importance and Distribution Ebeling (1959) considered purple scale to be as important as California red scale as a world-wide citrus pest. It is more widely distributed and prefers more humid climates. In recent years purple scale has been much less important both in Australia and in other parts of the world, for example in Florida (Muma, 1969), and this is due presumably to parasitism by *Aphytis* spp. wasps. It blemishes fruit and damages foliage, twigs and limbs. In New South Wales it is confined to the coastal region, mainly in areas close to the sea.

Conditions for Infestation Purple scale prefers warm moist situations which are shaded and protected from strong winds, such as in valleys near creeks. Thickly-foliaged trees, especially oranges and grapefruit, are most likely to be infested. Lemons and mandarins are susceptible, but are usually not heavily infested because of their more open growth habit.

Plants attacked Purple scale can attack a wide range of hosts, including camellia and holly, but is most often found on citrus.

Description and Life History The scale cover of the adult female is 2 to 3 millimetres long, mussel-shaped, straight or curved, and moderately convex. It is tough and leathery, and light to dark brown or purple-brown. There is a thin white membranous ventral cover under the insect's turgid white body. There are usually white oval eggs packed irregularly under the rear end of the scale cover.

The male scale cover is much smaller than that of the female, and narrower. It is roughly parallel-sided, light to dark brown, and often purple at the hind end. The adult male emerges from the cover as a delicate lavender-coloured two-winged insect.

The larvae hatch from eggs beneath the female scale as flat oval six-legged crawlers. They are mainly cream-coloured but are yellow at the rear end. They may move about for three days before settling permanently, usually where two surfaces are in contact or alongside some object – under calyx lobes, between touching leaves or fruits, under spider web, or beside a midrib or a particle of grit. The tendency to settle alongside grit probably explains why the undersides of the lower leaves in the skirts of trees are usually more heavily infested. The larvae prefer older leaves to young ones. The surface of young newly-set fruit

is not attractive, but they commonly settle beneath the calyx lobes.

On settling, the larva produces coarse white cottony threads from the anterior end, which form a mat above it. This 'fuzz stage' has a protective function while the larva begins to form the permanent scale cover from wax threads secreted at the posterior end. The cover is white and felt-like at first, but then it hardens and darkens. After 15 to 25 days moulting occurs.

In the second larval stage, the developing covers of the two sexes can be distinguished. The cover of the male is small and narrow; beneath it the developing insect goes through its second larval stage, as well as the short prepupal and pupal stages. The adult male emerges from under the cover about 50 days after hatching, and is short-lived. The female develops a mussel-shaped cover, and moults again about 20 to 25 days after the first moult. It is then fully adult and is soon fertilized by an adult male.

After fertilization the body of the female grows rapidly and egg deposition commences. The eggs are laid and accumulate beneath the cover as the parent's body shrinks. The first eggs hatch when the female is about 80 days old and a few larvae emerge each day for 80 to 100 days, and sometimes much longer, to produce an average total of about 150 larvae in spring and 70 in autumn (Hely and Gellatley, 1961). Generally there are two to two-and-a-half generations from spring until late autumn, with much overlapping.

During winter the scales develop slowly, and the females produce eggs. Some eggs hatch but mortality of larvae is high. The emergence rate of larval scales increases in spring, but the main spring hatching occurs between about mid-November and mid-December. Many crawlers then reach the young fruit and settle under the calyx lobes. Others settle on leaves, twigs and mature fruit (Valencias) usually close to the parent females. Young leaf and young twig tissue is not suitable for this scale. The main infestation of the surfaces of young fruits, in late summer or early autumn, is by larvae from the scales under the calyx lobes. By February–March, growing fruits touching each other in clusters are available to these larvae.

Many wandering larvae fall to the lower parts of the trees where they attach to leaves and twigs, especially where the vegetation is spattered with soil grit. Heavy populations on lower twigs and leaves are characteristic of purple scale infestation.

Injury Wood from 3 to 25 millimetres in diameter is most severely damaged, with much die-back. Large limbs weakened by purple scale are often heavily invaded by white louse scale, and part or all of the limb may die. Infested leaves show bright yellow blotches and heavily infested leaves will fall. Purple scale rarely damages young trees.

Purple scale is an ugly blemish on fruits, either as single scattered scales or as scales grouped where fruits touch each other or touch leaves. Infested fruits are difficult to clean; even after dead scales have been removed by washing and brushing, the fruit has a mottled dingy appearance and is greenish where the scales were attached. Scales will always be found under the fruit calyx lobes, even in lightly infested trees. The calyx lobes become dry and brown, and detract from the appearance of the harvested fruit. This infestation favours the development of stem-end rot, *Diaporthe citri* Wolf, a fungal decay.

Dispersal The usual means of introducing purple scale to an orchard is on young trees at planting. Infested buds or grafts can carry the scale to new trees in nurseries. Dispersal within the grove is most likely to be by the transport of larvae on visiting insects, birds or the clothing of orchard workers. Wind transport is unlikely to be important because of the protected situations in which infestations usually occur.

Purple scale.

Control measures

NATURAL Purple scale is attacked by parasites, predators and fungi. The wasps *Aphytis lepidosaphes* Compere and *A. columbi* Girault parasitize it commonly. The steel blue ladybird, *Halmus chalybeus*, and its larvae kill the scales and scatter the eggs when they lift the scale covers. Spraying with carbaryl in December–January for white wax scale control can increase purple scale considerably, which suggests that natural enemy insects are very important.

The red-headed fungus, *Fusarium coccophilum*, and felt fungi, *Septobasidium* spp., develop on purple scale, but their roles as control agents in New South Wales are not understood.

Hot dry conditions can kill purple scale. Extensive mortality of scales and eggs was seen at Gosford after the January 1939 heat wave (shade temperature 48°C).

APPLIED The timing of control measures is important. Ebeling (1959) stated that purple scale could be treated successfully with oil spray or hydrocyanic acid fumigation only when in the fuzz stage. In New South Wales, spraying timed to coincide with the two main larval emergence periods is successful. A post-bloom spray, before the new fruits press on to their calyx lobes, controls first-generation larvae. This is essential for adequate protection over the whole season against a heavy infestation. A second spray in about mid-February controls the second-generation larvae. Suitable sprays are recommended below.

POST-BLOOM	FEBRUARY
Maldison 0.1 per cent plus petroleum oil 1 per cent, or ethion 0.06 per cent-in-petroleum oil 1 per cent	Petroleum oil 2 per cent

It is often necessary to consider the effect on other pests and the compatibility of the spray with Bordeaux mixture fungicide. Maldison controls bronze orange bug and katydid, but is not compatible with Bordeaux mixture. Ethion (available as a

concentrate of 6 per cent ethion in petroleum oil) is compatible with Bordeaux mixture at strengths of up to 250 grams bluestone–250 grams lime–100 litres water.

White wax scale control requires a spray in mid-December or a little later. This is not a substitute for the post-bloom treatment against purple scale, but a December spraying can remove the need for the February treatment. Hely and Gellatley (1961) demonstrated good control of purple and white wax scales by spraying post-bloom and again in mid-December.

Carbaryl, which is very effective against white wax scale, can increase purple scale infestation so it should not be used on trees where this scale is a pest.

Natural enemies can give sufficient protection against purple scale on trees that are only lightly infested, or a single spraying in mid-February can be used. Petroleum oil 2 per cent or the sprays listed for post-bloom use are suitable.

Glover's scale *Insulaspis gloverii*

This scale is recorded occasionally in coastal districts, usually with purple scale. Like purple scale, it is found on trees in sheltered situations. It often has the habit of infesting thorns, or lying along the margin of the leaf or the edge of the petiole. Citrus is the only recorded host in New South Wales.

The scale cover of the adult female is 2.5 to 3 millimetres long, narrow and parallel-sided, and straight or curved. Other features distinguishing it from purple scale are that the eggs are arranged in two rows under the scale cover, and the lengthwise median division in the ventral covering.

General features of life history and development are similar for the two scale insects.

Control measures If required, they should be as for purple scale.

White louse scale *Unaspis citri*

Importance and Distribution This scale is typically seen on the trunks and main limbs of mature trees. It occurs in coastal districts and is most damaging if control is neglected.

It has a world-wide distribution in citrus-growing countries, where it is commonly called 'snow scale'.

Conditions for Infestation White louse scale develops best in humid regions, although in New South Wales coastal districts increase in infestation is favoured by dry seasons.

Plants attacked Other than citrus, no hosts have been recorded for white louse scale in New South Wales. Oranges, grapefruit, lemons and mandarins all support heavy infestation. Seedling trees appear to be more susceptible than commercial varieties.

Description and Life History The scale cover of the adult female is 1.5 to 2 millimetres long, dull brown or grey with grey margins, mussel-shaped but usually not curved, and has a lengthwise median ridge. The soft-bodied insect beneath the cover is orange. White louse scale females can be mistaken for purple scale females but, if they are turned over and squashed, the body juices of white louse scale are orange and those of purple scale are cloudy white.

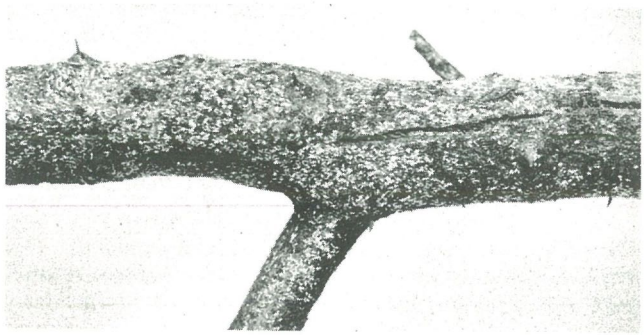
The male scale cover is white, with a soft felted texture. It is about 1 millimetre long, narrow and parallel-sided, with three longitudinal ridges. The white male scale covers give the scale its name. The adult male has an orange body and clear wings.

Eggs are produced by the adult female after fertilization by the winged male. They hatch quickly and do not accumulate under the scale cover. The active orange six-legged crawlers emerge and wander for a short period before attaching themselves permanently to the tree. They are attracted to light so tend to move towards the ends of twigs, or even on to fruits, especially if leaf-fall has occurred. Development follows the typical armoured scales pattern.

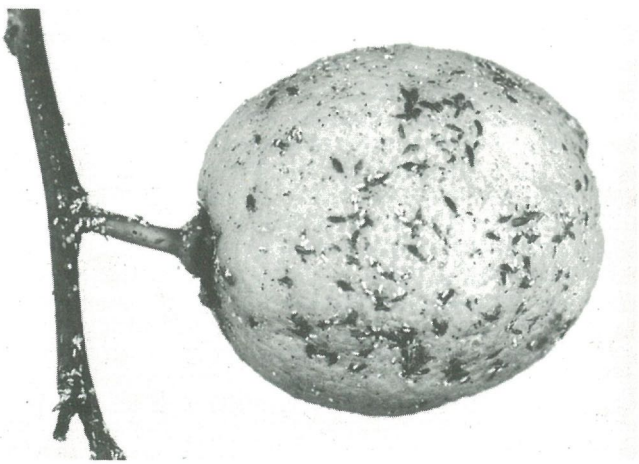
The time between permanent attachment to the tree and the production of the first young of the next generation is ten to twelve weeks in summer and longer in cooler weather. A female has been seen to produce 169 larvae in 146 days but the average number per female is about 80.

Several generations are produced per year, with much overlapping. Larvae are produced all through the year, but the rate is greatest in late spring, summer and autumn. Infestation usually builds to a peak by late autumn.

Injury It is unusual for trees under ten years old to be infested. Typical infestation is on the trunk and main limbs, but heavy infestation spreads to twigs, leaves and fruit. Young fruits, leaves or twigs are unsuitable. When cultured on young leaves, it has developed abnormally with distorted scale covers.



White louse scale on twig.



White louse scale on fruit.

White louse scale
Unaspis citri

1 Adult female scale; **2** adult female with scale covering removed; **3** male scale; all enlarged about twenty-five times. **4** Male and female scales on leaves and branch of tree; actual size.

Infestation results in yellow spotting and fall of leaves, twig die-back, and the weakening or even death of branches. The bark of heavily infested trunks and limbs looks tight and dull. Weakened limbs and twigs become infected by melanose fungus and attacked by borers. After white louse infestation has abated or been controlled, injured bark often cracks as the tree grows.

A severe infestation may look like whitewash on the trunk and limbs; at this stage a scale-eating caterpillar is usually present, and covering the bark with fine white webbing.

Dispersal The introduction of scales on nursery trees is not a very significant source of infestation. Visiting birds or insects are probably the main source of spread into orchards. Dispersal within the orchard is probably helped by transport of larvae on the clothing of orchard workers during harvesting, especially for Valencias and lemons picked in late spring, summer and autumn when the larvae are most numerous.

Control measures

NATURAL Parasites, predators and fungi undoubtedly protect coastal citrus trees from extreme damage by white louse scale. The most common parasite is *Aspidiotiphagus* sp. The red-headed fungus, *Fusarium coccophilum*, is commonly associated with white louse scale in wet seasons.

The predatory caterpillar, *Batrachedra* sp., causes spectacular reductions and shows up whenever populations become dense,

although the tree has usually been damaged by that time. These slender active caterpillars work under fine white webbing, and devour the scales voraciously. When fully fed, they pupate in groups with the pupae lying parallel to each other, often at branch forks. The adults are small fragile grey or brown moths with fringed wings.

If untreated, white louse scale infestations commonly develop to a climax and then rapidly decline. If this check did not occur, trees would undoubtedly be killed. Sometimes the need for treatment is not recognized until the infestation is declining, although still appearing to be severe. The tree may look white, but this will mainly be due to the webbing under which the predatory caterpillars are eating the scales.

APPLIED Spraying with lime-sulphur has been the accepted method of white louse scale control in New South Wales since before 1900, due to its effectiveness and despite leaf- and fruit-fall. Petroleum oil sprays are toxic to the scale but do not give good control on old bark, which absorbs much of the oil. Brooks and Thompson (1963) in Florida showed that some organophosphorus insecticides are effective.

Lime-sulphur treatment is usually required only every two or three years. Although spraying is effective against white louse scale at any time, the best time is winter when the trees are least likely to be damaged by the spray. From mid-June until the beginning of August when the spring shoots are about 5 millimetres long is the safest period. Risk of leaf- and fruit-fall, which is occasionally heavy, is increased by dry soil conditions, especially if there is a heavy crop. Poor tree health and the use of Bordeaux mixture spray on the trees earlier in the same season, even several months before the lime-sulphur, can also increase the risk.

Control spraying is recommended when there is a readily-detectable light infestation, before the scales increase to damaging numbers. Treatment of the inner framework of the tree is usually all that is required. Ideally this should be done with a hand-held spray rod. A suitable spraying strength is about 1.4 per cent calcium polysulphide, or 7 litres of lime-sulphur containing 20 per cent calcium polysulphide in 100 litres of water. The addition of a spreader, such as non-ionic surfactant at 20 millilitres per 100 litres, is recommended.

The special advantages of lime-sulphur for controlling white louse scale are due to its action against several different stages of the insect (Hely, 1944): adult males do not emerge from under the scale covers, immature scales neither develop normal scale covers nor, later, reproduce normally, and larval scales do not emerge from beneath the females. See page 19.

The appearance of the infestation does not change markedly after spraying with lime-sulphur. The scales present at spraying persist but do not reproduce, so the infestation gradually dies out.

Dispersible sulphur 0.4 per cent can be used against white louse scale in later autumn, winter or spring, avoiding the tree damage risk of lime-sulphur, but it gives control for only about twelve months. It can be applied as a mixture with Bordeaux fungicide in spring, but it is preferable to apply these sprays separately, as the sulphur is required mainly on the inner framework of the tree whereas the Bordeaux is required mainly on the canopy.

Circular black scale *Chrysomphalus aonidum*

Importance and Distribution This armoured scale has world-wide distribution in citrus areas, and in some, for example Israel (Cohen, 1969) and Florida (Muma, 1969), it has been an important pest until brought under biological control by the wasp parasite *Aphytis holoxanthus* DeBach. It is a serious pest of citrus in Queensland, and *A. holoxanthus* has been introduced to control it. In New South Wales it is of slight importance except in North Coast districts.

Plants attacked There is a large range of hosts, including holly and palms as well as citrus.

Description and Life History The scale cover of the adult female is circular, up to 2 millimetres in diameter, parchment-like and purple-black in colour. Its central point is slightly raised and surrounded by a red-brown band, and its margins are grey. The insect beneath the cover is light yellow. The male scale cover is elongate-oval and the mature winged adult male is orange with pale lilac wings.

Up to 300 eggs accumulate under the scale cover of each female. Active yellow crawlers hatch and settle close to the parent female. Several generations are produced in a year and generations overlap. The time from the emergence of a female crawler until it matures, is fertilized, and produces young is about nine weeks in summer.

Injury Both surfaces of leaves are infested and yellowish patches mark the feeding sites. Heavy infestation results in defoliation. The scales on fruit are an ugly blemish and prevent uniform colour development. Green twigs are sometimes infested but woodier parts of the tree are not attacked.

Control measures

NATURAL Black ladybird, *Rhizobius ventralis* (Erickson), steel blue ladybird, *Halmus chalybeus*, and *Orcus australasiae* are common predators. In Queensland an *Aphytis* sp. wasp, as well as the recently-introduced *A. holoxanthus*, parasitize the scale.

APPLIED Spray control measures, if required, should be as for California red scale.

SOFT SCALES

The general characteristics of soft scales are discussed on page 45.

White wax scale *Gascardia destructor*

Importance and Distribution This was commonly misidentified as Indian white wax scale, *Ceroplastes ceriferus* (Anderson), until Zeck (1932) showed that the species infesting citrus in Australia was *C. destructor*, and illustrated both scales. *C. ceriferus* does not infest citrus, but occurs on hopbush, *Dodonaea triquetra*, some ferns and some garden perennials.

In 1965, De Lotto placed *C. destructor* in the genus *Gascardia*. It is a native of Africa, although it does not infest citrus commonly there. It has been present in New South Wales since the

nineteenth century, as it is undoubtedly *G. destructor*, not *Ceroplastes ceriferus*, that was recorded by Allen *et al* (1898) as infesting citrus, and considered then 'probably introduced a good many years ago'.

White wax scale has been an important citrus pest in New South Wales, Queensland and Western Australia, but is of little significance elsewhere in the world. In New South Wales it is a coastal pest only, except for rather spasmodic infestations on the north-western slopes and plains. It does no direct observable injury, but produces honeydew that causes copious sooty mould development. Citrus orchards were commonly sprayed annually to prevent this.

During the 1970s, white wax scale in New South Wales dwindled to very low numbers. All the significant factors in this are not understood, but African parasites of white wax scale were established in 1968–72 (see page 47) and there was much destruction of the scale by heat in the summer 1972–73.

Conditions for Infestation White wax scale is a pest of subtropical and temperate climates with relatively high humidity in summer. It is killed by high temperatures in summer. It thrives best on vigorous trees, where it produces the largest individuals and, subsequently, the greatest numbers of eggs.

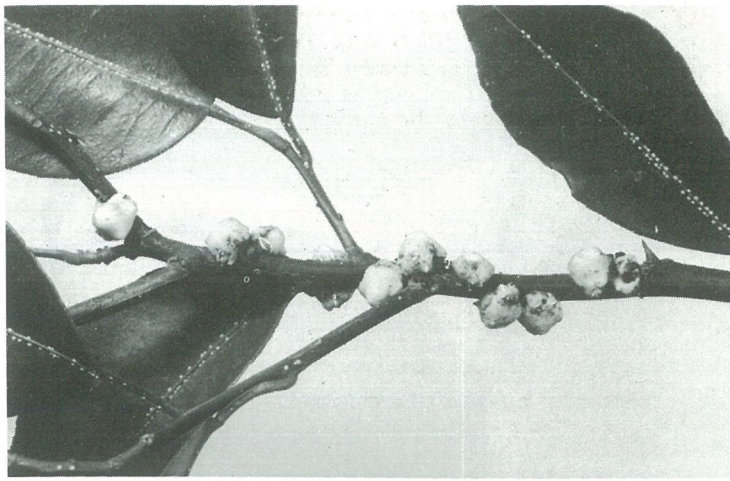
Plants attacked White wax scale has a very wide host range among both native and introduced plants, including ornamentals and weeds. All citrus varieties are hosts, and grapefruit probably supports the most numerous populations. Other fruit trees infested are guava, persimmon, mango and sometimes pear and quince. Gardenia, lillypilly, pittosporum and blackthorn, *Bursaria spinosum*, are commonly hosts. Oleander and japonica are frequently infested, but examples are sometimes seen of these and other shrubs adjacent to infested citrus but remaining quite clean. Turkey bush, *Elaeodendron australe* var. *angustifolia*, in north-western slopes and plains districts can be heavily infested. A detailed list of hosts in Queensland is given by Brimblecombe (1956).

Description and Life History Only the female scale is known in New South Wales. The adult female is enveloped in soft white wax, and may be about 10 millimetres long and 7 millimetres high, although many are only half that size. The chemical composition of the wax has been examined by Hackman (1951). The body of the insect beneath the wax is light red to dark brown, plump and soft. Its hind end narrows into the caudal process that lies flat on the leaf or twig. The Indian white wax scale, *Ceroplastes ceriferus*, has an elevated caudal process, and the insect's wax covering has a short down-turned horn at one end.

Egg development occurs during late winter, and egg-laying beneath the body of the insect begins in spring. As the eggs are laid the body shrinks upwards until its ventral surface is close to the dorsal surface, the insect is dead, and all the space beneath it is packed with the oval salmon-coloured eggs – up to 3000 in number (Zeck, 1934).

Climate and aspect determine the date of hatching, but in any one situation it is fairly constant from year to year; hatching commences in late October in warm districts and in December in cool situations. About five weeks elapse between the first and the last hatching on an infested tree – on the south side of the tree it is later than on the north side by one or two weeks (Hely and Levitt, 1950).

The larvae hatch from the eggs, and leave the space beneath the dead parent scale filled with the white remains of the hatched eggs. The larvae are light brown, oval, six-legged and about 0.5 millimetres long. They make their way towards the outside of the tree and settle, usually on a leaf but sometimes on a young green twig, and commence feeding. Probably because of their attraction to light, they tend to be on the upper surfaces of the leaves of orange, lemon and grapefruit, but on both surfaces of mandarin leaves which are more upright and therefore well lit on both sides. The larvae settle beside the midrib, or if that is crowded, beside a lesser vein. In heavy infestations they settle in two rows – one on each side of the midrib – and there may be as many as 200 larvae per leaf.



White wax scale adults and larvae.

Within a few hours of settling the larvae produce white marginal rays of felted material – four at each side, three in front and four at the rear – and a white felted pad on the dorsal surface. They remain on the leaf for four to five weeks, then move to the twigs and settle in permanent positions, usually on new or year-old wood. Feeding starts again and white wax production commences. A conical cap of wax is soon formed and the insect is at the 'peak' stage, which is followed a few weeks later by the 'dome' stage. The wax increases until the scale is fully developed by March or April. The insect beneath the wax is an adult at, or a little after, the peak stage.

While there is usually only one generation per year in Central Coast areas, small broods of larvae do sometimes appear other than in spring, notably in late winter. These do not change the general pattern. On the Far North Coast two fairly well-defined broods occur; the spring emergence is the main one, but there is another in autumn.

Sometimes larvae noticed at unusual times are main-generation larvae which either died or were killed and are still attached to the foliage.

Injury Both larvae and adults produce honeydew, which is seen at first as fine glistening droplets on the leaves, near the larvae. In humid conditions sooty mould fungi develop on the honeydew, and the black deposits may be abundant on foliage and fruit by late summer. The sooty mould can retard colour development of the new fruit, is unsightly on the fruit at harvest, and is difficult to remove completely by washing and brushing the fruit before packing.

Direct effects of the scales' feeding are negligible, and although sooty mould on the leaves may interfere with photosynthesis, no measurable effects have been observed.

The only simple type of carbohydrate present in the honeydew of white wax scale is ribitol (Hackman and Trikojus, 1952),

White wax scale
Gascardia destructor

1 Eggs; **2** first-stage larva, or 'crawler'; **3** first stage of wax formation on crawler; all enlarged twenty-five times. **4** Adult female with waxy covering removed; enlarged nine times. **5** Citrus twigs and leaves infested with the scales; actual size. Sooty mould developing on leaves.

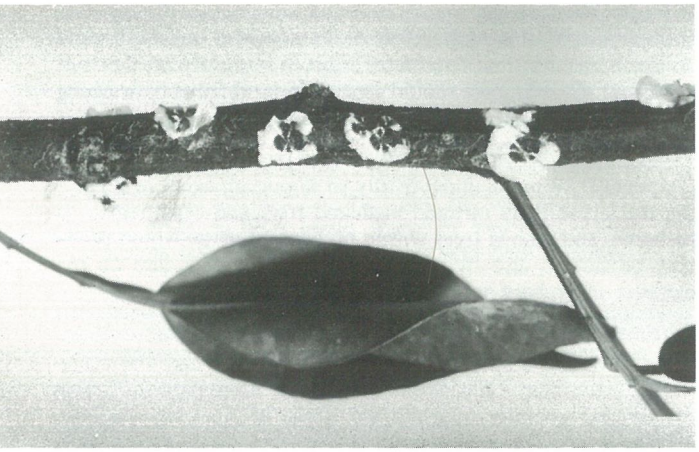
which is a very satisfactory medium for the growth of sooty mould fungi (Frazer, 1937). This honeydew is not attractive to ants; ants seen moving among white wax scale colonies will be seeking brown scales or mealybugs.

Dispersal Nursery trees are not a common source of the introduction of white wax scale to orchards, owing to its conspicuous appearance. Within orchards the larvae are easily transported by wind, by visiting insects and birds, and on the clothing of orchard workers harvesting Valencias and lemons, for example.

First-stage larvae have been observed to be carried by wind for 30 metres and second-stage larvae, which bear the dorsal pad and marginal rays, for 12 metres (Hely, 1960). This wind transport of second-stage larvae explains how trees can be reinfested after effective spraying from nearby untreated orchard trees, windbreaks, ornamentals, or bush trees.

Control measures

NATURAL White wax scale is very vulnerable to heat, especially during the larval stages. Mortality of larvae occurs when temperatures exceed about 41°C. Following a temperature of 44.4°C at Gosford, in December 1951, counts showed a mortality in larvae on the leaves of between 60 per cent and almost 100 per cent. The record temperature of 48°C at Gosford in January 1939 resulted in almost complete mortality of the scale



White wax scales destroyed by birds.

in many lowland coastal districts. This heat mortality is greatest on trees suffering stress from dryness.

Before the late 1960s there had been no effective parasites of white wax scale in New South Wales, despite the attempt by Gurney (1936) to introduce them from Africa. During 1968–72, Snowball released the African parasitic wasps *Anicetus communis* and *Paraceraptrocerus nyasicus* in New South Wales following his study of parasites of white wax scale in South Africa (Snowball, 1968). These important natural enemies of white wax scale became successfully established and, although all significant factors involved are not understood, they have contributed to the reduction of white wax scale populations to unimportant levels.

Predators reduce white wax scale populations, although they do not control them. The steel blue ladybird, *Halmus chalybeus*, adults and larvae destroy the scale larvae on the leaves. Spring application of Bordeaux mixture is followed by increased white wax scale infestation in the next year; this is believed to be due to the repellent effect of Bordeaux residues on ladybirds.

Birds sometimes kill many white wax scale adults in winter-spring by pecking through the wax to eat the insect beneath. Eastern spinebill, *Acanthorhyncus tenuirostris*, silver eye, *Zosterops lateralis*, and yellow-tailed thornbill, *Acanthiza chrysorrhoa*, have been observed doing this.

Honeybees occasionally take the wax in the spring and leave the scale bodies exposed. Resulting mortality has not been observed and it may depend on the extent of egg development within the scale body. Once the eggs have developed within the body, the scales can be removed from the twigs – as specimens placed in dry tubes in spring, for example – and the eggs will be deposited and hatch normally.

APPLIED In Central Coast orchards, where there is only one main generation per year, white wax scale may be controlled by spraying with petroleum oil emulsion at 2 per cent dilution when almost all the larvae are on the leaves or stems. This is before they move to permanent positions on the stems and cover themselves with wax which will protect the insect from most sprays. Thorough coverage spraying of the foliage canopy is necessary. This spray should be applied immediately after egg-hatching is complete on the south sides of the trees. It will be on almost the same date each year for any one orchard, but the date varies from orchard to orchard depending on climate and aspect – from mid-December in lowland areas to mid-January in highland areas. To check for egg-hatching, adults are turned over and examined with a lens to distinguish between plump lustrous unhatched eggs, flat dull dead eggs, and the white remnants of hatched eggs. The success of this method has been demonstrated by Hely and Levitt (1950) and by subsequent experiments in coastal New South Wales comparing organophosphorus and carbamate insecticides with petroleum oil at this timing.

Some organophosphorus insecticides, such as azinphos-methyl, carbophenothion, dimethoate, maldison and phosmet, have proved to be effective at this timing, especially in a mixture with petroleum oil 1 per cent. The organophosphorus insecticide methidathion alone, and the carbamates carbaryl and promecarb in mixture with petroleum oil 1 per cent, have proved to be outstandingly effective; they will also kill the young scales after wax formation has commenced – at least until the peak stage. Some experiments have shown that carbaryl can cause severe increase in purple scale infestation.

Strongly alkaline soda solutions have been used for many years against white wax scale – at the peak to dome stages in January to March. They dissolve the young insects' wax but often damage trees or fruit, and they are not reliable especially when followed closely by rain. Another disadvantage is that much sooty mould may have developed on honeydew from the scale larvae before this later spraying is carried out.

Soda spray commonly causes slight black speck blemishing of fruit. This occurs particularly when the fruit is bigger than a golf ball at the time of spraying, so navels are most likely to be affected. Soda also often causes leaf- and fruit-fall, especially in hot weather, or on trees suffering moisture stress, or on trees sprayed with Bordeaux earlier in the season.

The concentrations for soda spraying are 1 to 1.3 kilograms soda ash or 3 to 4 kilograms fresh washing soda, plus 500 millilitres white oil or 1 litre liquid soap, in 100 litres water. The lower concentrations are used against peak stage and the higher rates against dome stage scales. The washing soda crystals must be fresh, as they give up water to the atmosphere, unless stored in sealed containers, and so increase in active ingredient content per unit mass.

Current recommended control measures against white wax scale are summarized below.

Spray the foliage canopy thoroughly, immediately after hatching is complete on the south sides of the trees.

LIGHT INFESTATIONS Use petroleum oil 2 per cent, or maldison 0.1 per cent plus petroleum oil 1 per cent.

HEAVY INFESTATIONS (or if spraying is delayed to the peak stage). Use carbaryl 0.05 per cent plus petroleum oil 1 per cent, or promecarb 0.05 per cent plus petroleum oil 1 per cent, or methidathion 0.05 per cent.

Carbaryl should not be used if purple scale is present, as it can cause severe increase of that serious pest. The probability of a similar risk using promecarb has not been established. Methidathion is more toxic to the user than most other insecticides used on citrus.

Spraying with petroleum oil 2 per cent is the preferred treatment for routine control of white wax scale, as it is likely to be the least harmful to useful natural enemy insects such as wasp parasites of California red scale.

Pink wax scale *Ceroplastes rubens*

Importance and Distribution This scale causes sooty mould on trees and fruit. It is found in coastal New South Wales as a pest mainly of mandarins, but is more important on the Far North Coast and in Queensland. It is common in Japan, India, South East Asia, Fiji and Hawaii.

Conditions for Infestation Pink wax scale requires a relatively humid climate. It does best on trees in sheltered low-lying situations. On native hosts, such as lillypilly, it is notably present along watercourses.

Plants attacked Mandarin is the preferred host but heavy infestation can occur on grapefruit, kumquat and lime. Seedling oranges are preferred to commercial orange varieties. Lemons are rarely infested. Summerville (1934) records strong preference for vigorous trees with abundant new growth when the larvae are active.

Other cultivated fruit trees attacked are avocado, custard apple and mango. Pittosporum, lillypilly, ivy, holly and some ferns are commonly infested.

Description and Life History The wax cover of the adult female is hard, pink, 3 to 4 millimetres long, almost globular and smooth, with a slight depression on the top and two lobes on each side. The insect body beneath the cover is soft and pink to red-brown. Males are not known in New South Wales.

Up to 700 eggs (Blumberg, 1935) are laid beneath the adult female body, which shrinks upwards until the insect is dead and the space beneath it is filled with eggs. Active purple-red larvae hatch from the eggs and crawl about, sometimes for several days, before settling on a leaf, usually over a vein or on a young shoot. The larvae quickly secrete a white cap, and subsequently the pink wax starts to develop as a band below the white cap. Once it has settled, the insect rarely moves. There are two generations per year, with larvae appearing in November–December, and April–May.

Pink wax scale.

Injury Direct injury to the trees seems negligible, but the scale is objectionable due to the copious development of sooty mould on the honeydew that it secretes. This is unsightly on the fruit at harvest. Cleaning the mould from mandarin fruits by washing and brushing before packing is particularly difficult because of their rough-textured soft skins.

Dispersal Wind is undoubtedly an important agent in spreading the larvae from infested bushland trees and ornamentals to orchards, and among trees within orchards. Larvae would probably be carried also by visiting birds and insects, and on the clothing of orchard workers.

Control measures

NATURAL Five species of ladybirds, a lacewing, the scale-eating caterpillar, *Catoblemma dubia*, and three parasitic wasps are natural enemies of pink wax scale in Australia (Wilson, 1960).

APPLIED The sprays used against white wax scale larvae on the foliage can be effective in summer against young pink wax scales, if used before they are bigger than a pinhead. The treatment may be less successful if uneven hatching should result in the larvae not being uniformly unprotected by wax development at spraying time. Soda sprays have often been used.

Spraying with methidathion, when the first-emerged larvae are slightly larger than a pinhead, has been recommended as a result of seasonal history and control studies in Queensland (Smith, 1976). The dilution rate is methidathion 0.05 per cent plus petroleum oil 1 per cent, or methidathion 0.05 per cent without oil for mandarin varieties which are subject to oil-spray damage.

Chinese wax scale *Ceroplastes sinensis*

Importance and Distribution This scale insect sometimes causes copious sooty mould development on trees and fruit. It was first recorded in Australia in 1966, in Sydney, but it has subsequently spread extensively in coastal citrus districts. It occurs widely in other parts of the world, such as Spain, Italy, North Africa, China, Solomon Islands and New Zealand.

Plants attacked There is a wide range of hosts, in addition to citrus, and in New South Wales these include boxthorn, lillypilly and tea-trees, *Melaleuca* spp. (Snowball, 1970).

Description and Life History The mature adult female is enveloped in hard wax. During summer this wax is up to 7 millimetres long, 5 millimetres wide and 4 millimetres high, and grey-brown with one apical and six marginal dark spots. The eggs are laid in summer beneath the soft body of the insect. The body shrinks upwards until it is dead and the space beneath it is packed with thousands of the plump purple-red eggs. The eggs hatch in late summer-autumn – up to the end of March near Sydney – and the brown six-legged larvae crawl out on to the leaves and settle along the veins, usually on the upper surfaces. They develop prominent white ornamentations – three marginal rays on each side, three smaller rays at the anterior end, four at the posterior end, and two tall dorsal pads. This is called the 'rosette' stage.

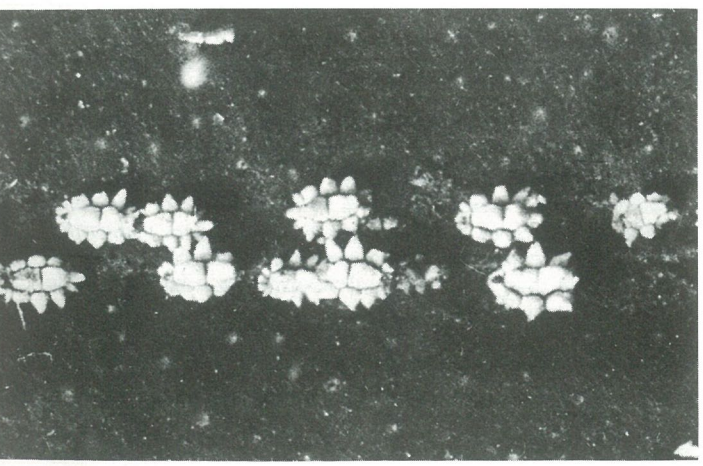
The young scales remain on the leaves until early winter – when they move to the stems and settle again – usually as young

adults with a prominent cover of hard red-pink body wax, and with the white ornamentations still attached. As the insect and the wax enveloping it increase in size, the white ornamentations erode away and the pink colour of the wax changes slowly to white. During spring, the wax is distinctly white on the anterior half and pink on the posterior half.

A low incidence of males – distinguishable from the females as ornamented larvae by a prolonged anterior white ray – has been recorded in New South Wales by Snowball (1970).

There is one main generation per year near Sydney.

Chinese wax scale adults and larvae.



Close-up of Chinese wax scale larvae showing marginal rays and dorsal pads.

Injury Direct injury to the trees seems to be negligible, but there can be copious production of sooty mould on honeydew produced by the insects. This is unsightly on the fruit at harvest and cleaning the mould off before marketing the fruit can be difficult.

Dispersal Wind transport of larvae is a means of dispersal. It is probable that larvae would also be carried by visiting birds and insects, and on the clothing of orchard workers.

Control measures

NATURAL Increase in scale numbers from generation to generation is sometimes spectacular, but often it is not great which indicates that natural factors have intervened. Natural enemies recorded in Sydney include wasp parasites, the wasp *Scutellista cyanea* Motschulsky which is predatory on eggs, predatory ladybirds, thrips, caterpillars and birds (Snowball, 1970). Snowball concluded that these enemies were unlikely to influence abundance, and considered weather which affected larvae and females moving from leaves to stems to be more important. Populations are probably very vulnerable to wastage by falling from trees, either as the heavily burdened young females when moving, or as the cumbersomely-ornamented larvae dislodged by wet and windy weather.

APPLIED Spraying at the end of March, after all the eggs have hatched and the young scales are in the rosette stage, with petroleum oil 1.25 per cent is effective.

Black scale *Saissetia oleae*

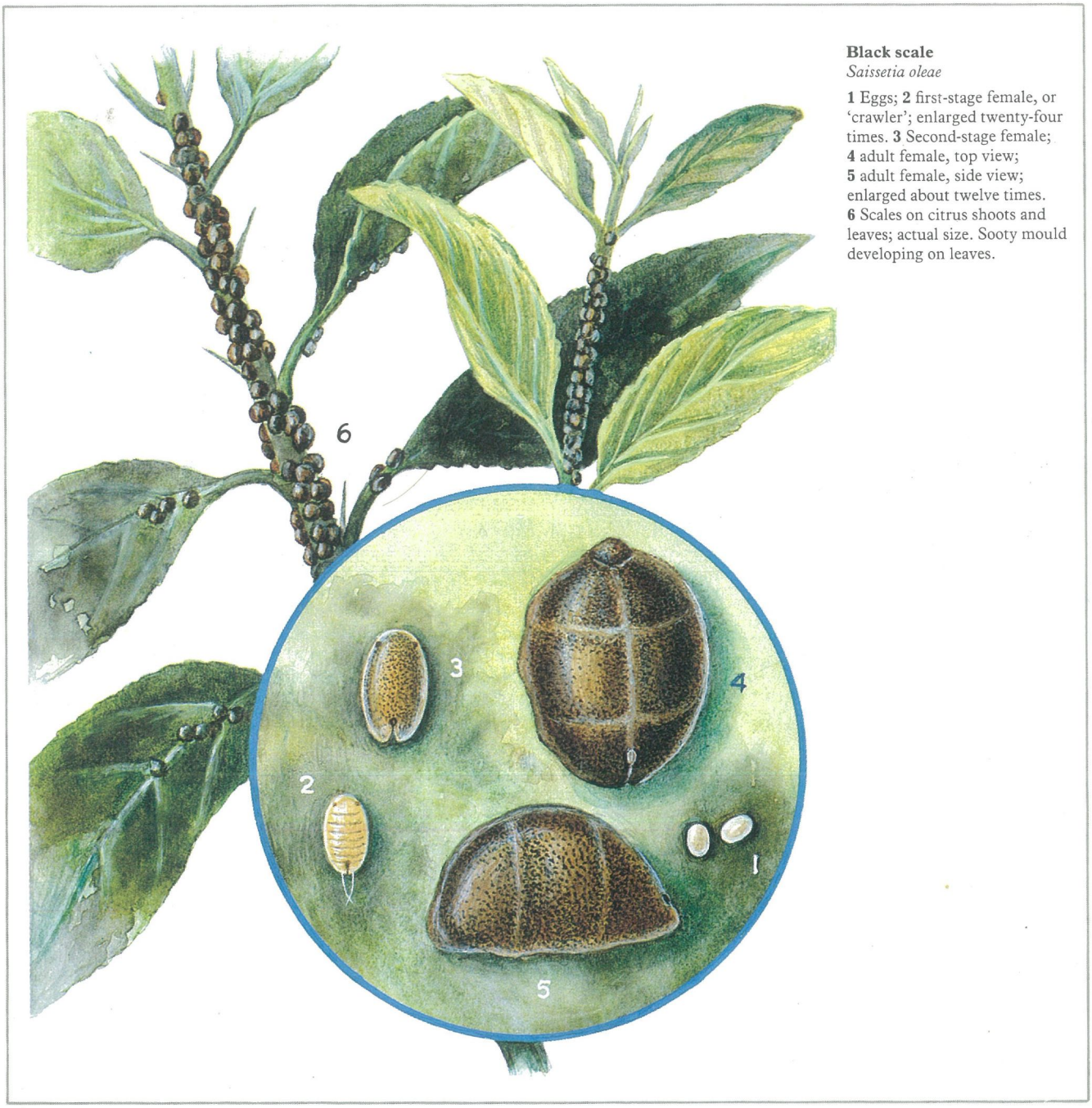
Importance and Distribution This species has a world-wide distribution. It has been a pest of citrus in New South Wales for a very long time; during the nineteenth century it was called 'black bug' or 'turtle bug'. More recently it has been called 'brown olive scale'.

It is found in both coastal and inland regions and it is most often important as a pest in citrus nurseries. Widespread infestation of mature trees has been seen most commonly in Lower Murray orchards. Severe infestation results in extensive growth of sooty mould on trees and fruit and sometimes in leaf-fall.

Conditions for Infestation Temperate climates with fairly high humidity suit this species. Neither very dry and hot nor tropical climates favour it.

Plants attacked All varieties of citrus are susceptible to infestation, with grapefruit being the most susceptible. Trees in good vigour usually support the largest and greatest numbers of scales. Many hosts other than citrus may be attacked, including olive, passionfruit, oleander, hibiscus, gardenia, jacaranda, and perennial daisies. The scale has been seen also on annual plants such as melons.

Description and Life History The adult female, when fully mature, is bun-shaped, about 3 millimetres long, 2 millimetres wide and 2 millimetres high. Its upper surface is dark brown or black, tough, leathery and smooth, and often has tiny flakes of waxy material. Ridges on the back form a raised H-shape. A female deposits about 2000 eggs under her body, which shrinks upwards until the insect is dead and the space beneath is packed



Black scale
Saissetia oleae

1 Eggs; **2** first-stage female, or 'crawler'; enlarged twenty-four times. **3** Second-stage female; **4** adult female, top view; **5** adult female, side view; enlarged about twelve times. **6** Scales on citrus shoots and leaves; actual size. Sooty mould developing on leaves.

with eggs. After hatching the larvae move over the plant for a day or two until they settle on leaves, preferably beside the mid-rib, or on young shoots. They are about 0.5 millimetres long and light brown. They remain on the leaves for four to eight weeks before moulting to a larger form with a longitudinal ridge. They usually remain settled for a further four to six weeks before moulting again, and moving to the twigs to take up permanent positions where they grow rapidly. The young adults, before egg-laying, are dark mottled grey, softer and less humped than later, and are referred to as the 'rubber' stage.

Male scales, which are distinguishable after the first moult as more elongate than the females, develop under a narrow light brown cover and are not often seen.

The time elapsed from the settling of the crawler to the production of the next generation of eggs is about four months. There are two main generations per year with hatching periods in December–January and in autumn, but there can be overlapping broods which result in infestations of scales of two distinct age groups. Autumn-hatched scales often mature on the leaves.

Black scale.

Honeydew is produced by larvae and adults, particularly in the early adult stage. It is extremely attractive to ants, especially small black ants, *Iridomyrmex* sp. They are more notably attracted and active at the time of emergence of the scale larvae.

Injury In heavy infestations, foliage and fruit become thickly covered with sooty mould which has developed on the insects' honeydew. It is difficult to remove this completely from fruit by washing and brushing before marketing. Heavy infestations and copious sooty mould cause loss of vigour, especially on young trees, and there may also be a loss of foliage. Twig die-back is sometimes associated, but this is more likely to be due to flourishing California red scale as the ants attending black scale also protect red scale from natural enemies.

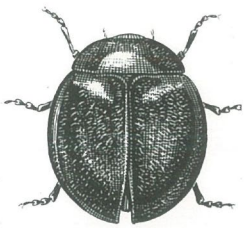
Dispersal Black scale occurs commonly on young trees, such as those in citrus nurseries, so they are a ready source for the introduction of the scale to new orchards. It is spread readily by wind within orchards – Quayle (1916) demonstrated wind transport of larvae for 137 metres – and by visiting birds and insects and on clothing of orchard workers. In new orchards, ants may carry the larvae from tree to tree.

Control measures

NATURAL Very hot weather can cause high mortality. At Dareton, in the summer of 1965, it was seen that on a single hot day when the temperature reached 44°C there was almost 100 per cent mortality of eggs and crawlers beneath the parent scales, although settled larvae on leaves mostly survived.

Many wasp parasites, some native and some either accidentally or deliberately introduced, attack black scale in New South Wales, and scales showing parasite emergence holes are often seen. Of these wasps, *Metaphycus lounsburyi* Howard and *Coccophagus* spp. are common true parasites, and the larvae of *Scutellista cyanea* are commonly predatory on eggs under parent scales.

The larvae of green lacewings, *Chrysopa* spp. and the larvae and adults of ladybirds such as the black ladybird, *Rhizobius ventralis*, and the mealybug ladybird, *Cryptolaemus montrouzieri* Mulsant, are useful predators. The scale-eating caterpillar, *Catoblemma dubia*, which forms grey parchment-like cocoons ornamented with the remnants of scale coverings, is frequently seen attacking heavy infestations.



Black ladybird, a predator on black scale. (Length about 3 mm.)

Entomogenous fungi, including *Nectria* spp., sometimes attack black scale, especially in warm moist autumns.

Ants affect the efficiency of wasp parasites of black scale. Their constant traffic over the scale colonies disturbs the wasps and reduces their egg-laying and feeding. Control of ants results in a rapid improvement in the scale situation. This was seen by Pasfield (unpublished data, 1950) in a Sydney suburb where the Argentine ant had been eradicated. Oleanders planted as street ornamentals had been heavily infested by black scale, but when the ants were eliminated the infestations declined and disappeared. Apart from their effects on parasites, ants remove the honeydew that would otherwise contaminate the scales, as has been shown by Way (1954) with another species of *Saissetia*.

APPLIED Thorough coverage spraying of the tree canopies in December–January, when most of the eggs have hatched, with petroleum oil 2 per cent, or maldison 0.1 per cent plus petroleum oil 1 per cent, or ethion 0.075 per cent-in-petroleum oil 1.25 per cent, or carbaryl 0.05 per cent plus petroleum oil 1 per cent is recommended. This kills young scales but not eggs or adults from the rubber stage onwards. Carbaryl should not be used if purple scale is present, as it can severely increase that serious pest.

Intense ant activity on the trees usually indicates that the eggs are hatching and the larvae are settling. To check that egg-hatching is complete, turn adults over and examine them with a lens to distinguish between the plump unhatched eggs and the white remnants of hatched eggs.

Eliminating ant activity on the trees assists natural enemies and so reduces black scale problems. This is done by spraying chlordane 2 per cent lightly over the trunks, the soil beneath the trees, and ant nests in and near the orchard.

Soft brown scale *Coccus hesperidum*

Importance and Distribution This world-wide species blackens trees and fruit with sooty mould developed on its copious honeydew. In New South Wales it is a common pest of nursery trees. In the orchard it is more troublesome in inland than in coastal districts. It mainly affects trees up to ten years old; on mature trees infestation is usually only on part of the tree.

Conditions for Infestation Soft brown scale is favoured by warm dry climates.

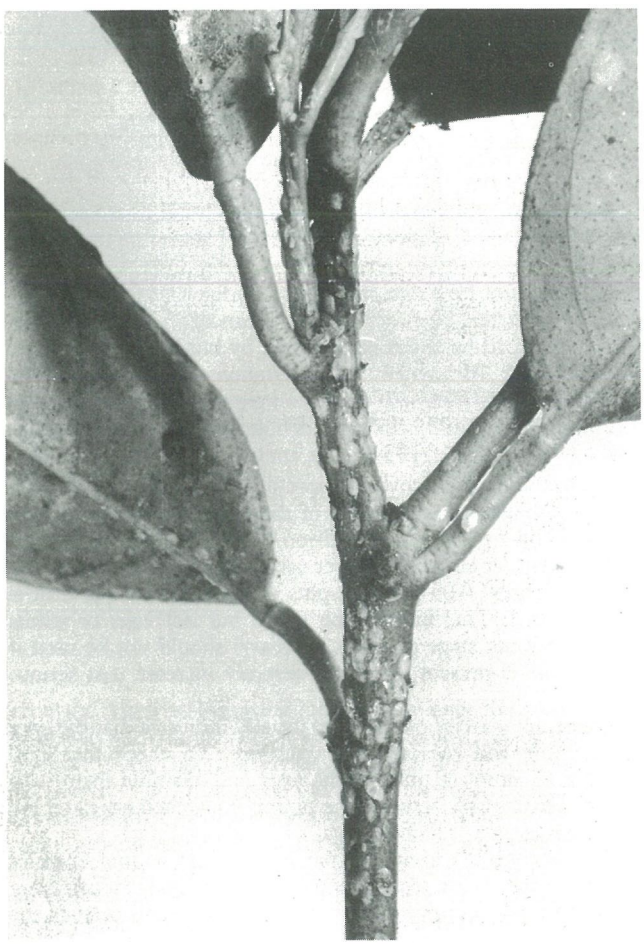
Plants attacked All varieties of citrus are attacked, with grapefruit being preferred. There is a wide range of other hosts, including fig, daphne, oleander, camellia and palms.

Description and Life History The mature female is soft, fairly flat, 3 to 5 millimetres long, approximately oval and mottled yellow-green to brown. It has functional legs and can move about until the late adult stage. The oval flattened larvae are greenish yellow.

Soft brown scale has been considered to be viviparous, but this is not correct. Eggs are laid at the rate of a few per day, and hatching follows so quickly that they are rarely seen. The larva hatches shortly after the egg is laid under the parent female, and moves out when the parent from time to time raises the posterior part of its body (Annecke, 1966). The larvae settle along the mid-veins on either surface of leaves and on petioles, fruit stalks and young shoots. They moult first after three or four weeks, and again after another month. Egg-laying usually begins several weeks later. The average egg production per female has been estimated at 70 and the egg-laying period at two months (Bodenheimer, 1951). The total time from when a larva settles until it produces its first young may be from just over two months to as much as four months. Several generations normally occur each year, with individuals at various stages of development existing together and larvae emerging in large numbers at any time in the warmer months.

Male scales have not been recorded in New South Wales.

The larvae and adults produce a great deal of honeydew, and ants feed avidly on this. The honeydew may be so abundant that it drips from the trees. Ant activity is associated with soft brown scale, and sometimes infestations of the scale may be confined to trees near ant nests.



Soft brown scale.

Injury The main harm is from heavy sooty mould development on trees and fruit due to copious honeydew production.

Dispersal Soft brown scales may be taken in to an orchard on nursery trees, and spread within orchards as larvae by wind, visiting birds and insects, and on the clothing of orchard workers. Ants frequently colonize the scales and introduce them to trees.

Control measures

NATURAL Soft brown scale is attacked by many natural enemies including wasp parasites, especially *Coccophagus scutellaris* (Dalman), and predators such as black ladybird, *Rhizobius ventralis*, mealybug ladybird, *Cryptolaemus montrouzieri*, and the scale-eating caterpillar, *Catoblemma dubia*.

The importance of natural enemies in restricting soft brown scale has been indicated by the increased infestation with the scale after spraying with parathion (Annecke, 1959), and by the development of massive infestations after spraying with DDT (Wilson, 1960).

APPLIED Spraying in summer, preferably when most scales are young, with petroleum oil 2 per cent, or maldison 0.1 per cent plus petroleum oil 1 per cent, or ethion 0.075 per cent-in-petroleum oil 1.25 per cent is recommended.

Control of ants in the orchard can assist soft brown scale control (Hely and Duncan, 1959). Use of chlordane 2 per cent spray against ants is recommended, if applied lightly over the trunks, the soil beneath the trees, and to ant nests in and near the orchard.

Citricola scale *Coccus pseudomagnoliarum*

Importance and Distribution Citricola scale is known in California, Mexico, Japan, Russia, Iran and Australia. In California it has been an important pest infesting citrus trees heavily enough to weaken them by sucking sap, and blackening them with sooty mould which has developed on the copious honeydew. It has been known in New South Wales for over 30 years but is rarely present in heavy infestation, except in young orchards. It is confined to the Murrumbidgee Irrigation Area and Murray River districts.

Plants attacked Citrus is the only recorded host in New South Wales.

Description and Life History The general appearance is similar to soft brown scale, but the mature adult is grey, larger and more convex. Several other features assist in distinguishing citricola scale from soft brown scale.

- ☐ At any one time all the citricola scales on the tree are at the same developmental stage; soft brown scales may be present in a number of different developmental stages.
- ☐ Citricola scales mature on the twigs; soft brown scales mature on leaves and twigs.
- ☐ Eggs are usually obvious under mature citricola scales but not under mature soft brown scales.

Citricola scale.

There is only one generation per year. The mature adult female deposits the eggs under her body in late spring, and the larva hatches several days after the egg is laid. The larvae wander for a day or two before settling on the leaves, generally on the undersides. They are oval, very flat, yellow-green and transparent. After five or six weeks they moult, become larger and gradually darken, then moult again after a further five or six weeks. They stay on the leaves until autumn, then migrate to the twigs and settle on young wood. These scales grow rapidly in early spring, and begin to lay eggs under their bodies in November. The female produces 1000 to 1500 eggs in an egg-laying period of four to six weeks (Ebeling, 1959). The adult female dies when egg production is complete, becomes brown and detached from the twig, leaving a white oval mark.

Male scales have not been observed in New South Wales. Ebeling (1959) records that the males are rare in California.

Injury Sooty mould develops heavily on trees and fruit as the scales produce honeydew abundantly. The honeydew is not very attractive to ants except during the hatching and settling of larvae.

Control measures

NATURAL The natural enemies have not been studied in Australia. In California, the parasites which commonly attack soft brown scale also attack citricola scale.

APPLIED No experiments have been carried out in New South Wales, but good results have been noted following the use of petroleum oil 2 per cent spray in summer after the emergence of larvae was complete. It is expected that maldison 0.1 per cent plus petroleum oil 1 per cent or ethion 0.075 per cent-in-petroleum oil 1.25 per cent would also be effective at this timing.

Cottony cushion scale *Icerya purchasi*

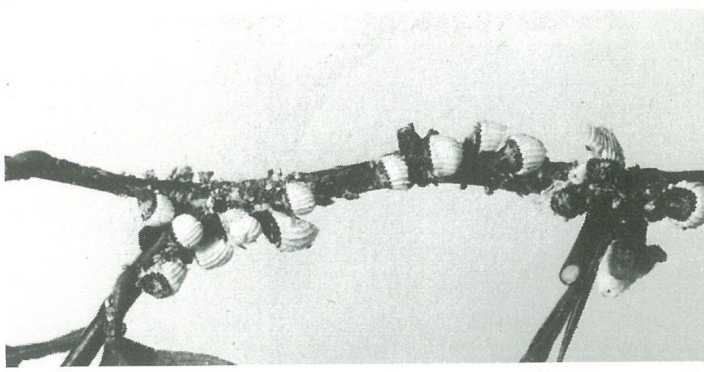
Importance and Distribution The dramatic success in California of the biological control of this insect by the vedalia ladybird, *Rodolia cardinalis*, taken from Australia in 1888, is described on page 46. (Cottony cushion scale has been credited by Ebeling (1950) with being responsible for the following important phases of economic entomology in California – biological control, HCN fumigation, oil sprays and quarantine.)

Cottony cushion scale is widely distributed through the citrus-growing countries of the world, but in all of them its natural enemies, especially vedalia, have brought it under satisfactory control. It is a native of Australia and may be found in all the citrus districts of New South Wales. In outdoor situations it is usually suppressed by its natural enemies, but heavy infestations sometimes develop temporarily on young trees. Infestation can be severe in glasshouses, where natural enemies are excluded.

Conditions for Infestation Cottony cushion scale is suited by both the humid conditions of coastal districts and the more dry environment of inland irrigated orchards.

Plants attacked It has a wide range of hosts especially *Acacia* spp., *Pittosporum* sp., *Grevillea* spp. and many fruit trees, ornamentals and weeds.

Description and Life History The body of the mature female is red-brown, about 5 millimetres long, and may be covered with a white mealy secretion. The legs are black. The eggs are laid beneath the body into the ovisac, which develops as a soft cottony mass with a white fluted surface. The ovisac adds about 10 millimetres to the length of the insect, and may contain about 1000 oval red eggs.



Cottony cushion scale.

The bright red larvae, with dark legs and antennae, hatch from the eggs and emerge from the ovisac. They develop through three stages before becoming adult. At first they have a series of yellow tufts on the back and around the margins, and a long hair, often with a drop of clear liquid, at the rear end. In the later stages, the body is orange-brown, with long fine hairs and tufts of yellow mealy material. The early-stage larvae settle along the mid-veins on the undersurfaces of leaves. The older stages migrate to twigs or older branches, or even to the trunks of the trees. The young stages and the adult can move actively until the ovisac develops.

Honeydew is secreted abundantly, and is very attractive to ants.

Adult males, which are not commonly seen, are about 3 millimetres long, and orange-red with black markings and brown wings. The abdomen terminates in two thick cylindrical processes.

The time elapsed from the appearance of larvae to the next crop of young emerging from the ovisac is from four to six months. There are at least two main generations per year, with young being produced in February-March and August-September, but ovisacs with eggs can be found in all months.

Injury Sooty mould from the insects' honeydew blackens trees and fruit.

Dispersal Dissemination by wind, insects and birds is undoubtedly important. Ants have been seen to transport young scales on to citrus trees and set up colonies.

Control measures

NATURAL The natural enemy insects can usually keep infestations at extremely low levels. The vedalia ladybird, *Rodolia cardinalis* (Mulsant), is the most important enemy. Its larvae feed on the eggs in the ovisacs and, later, the larvae and adults attack all stages of scales. They seem to feed only on this scale. The adult beetles are nearly hemispherical and about 3 millimetres long, with red and black markings.

Some other ladybirds, such as black ladybird, *Rhizobius ventralis*, and mealybug ladybird, *Cryptolaemus montrouzieri*, also attack cottony cushion scale. The small fly *Cryptochaetum iceryae* (Williston) parasitizes the scale and is a most effective enemy. It develops within the body of the scale, and the adult emerges through a hole with a circular cap like a trapdoor. It is about 1.5 millimetres long, and metallic-blue.

APPLIED Artificial control is rarely needed. If it should be required, petroleum oil 2 per cent or maldison 0.1 per cent plus petroleum oil 1 per cent spray could be used. As these sprays do not kill the eggs in the ovisacs, a repeat spraying may be needed several weeks later after the eggs have hatched. Petroleum oil 2 per cent should not be used twice, as this can be detrimental to tree health and fruit quality.

Long-tailed mealybug *Pseudococcus longispinus*
Citrus mealybug *Planococcus citri*
Citrophilous mealybug *Pseudococcus calceolariae*

Importance and Distribution Mealybugs have world-wide distribution on many plants. They are common in coastal and inland districts, but in New South Wales they only rarely achieve their potential as serious pests of citrus. The three most common species on citrus in New South Wales are long-tailed mealybug, citrus mealybug, and citrophilous mealybug. In coastal districts *Rastrococcus* sp. is often seen on citrus leaves, but infestations are transient and unimportant.

Conditions for Infestation Mealybugs are generally suited by warm humid conditions, such as those found in glasshouses. Conditions in thickly-foliaged trees in inland irrigated orchards are sometimes suitable. In South Australia, humidity has been shown to be a limiting factor for the long-tailed mealybug (Browning, 1959). Hot dry conditions prevented its increase and shelter, such as spider webbing, assisted survival.

Plants attacked All citrus varieties may be attacked but mature thickly-foliaged trees suit these insects best. Many cultivated and ornamental trees and plants are hosts.

Description and Life History Mealybugs all have soft oval convex and distinctly segmented bodies, though divisions between head, thorax and abdomen are not evident. They are covered with white mealy wax and have a fringe of marginal filaments. They have legs and can move through most of their life. They may grow to a length of 6 millimetres. When disturbed, they exude drops of fluid from dorsal glandular pits. The colour of the fluid can assist field identification.

The distinguishing features of the three species are described below.

Mealybugs. (Length up to 6 mm) P.R.I., Dept of Ag. Vic.

LONG-TAILED MEALYBUG Anal filaments are usually at least as long as the body; glandular exudate is almost colourless-yellow; eggs are laid beneath the body and hatch almost as soon as laid.

CITRUS MEALYBUG Anal filaments are not more than one-quarter the length of the body; dark body colour showing in a median dorsal stripe; glandular exudate is yellow-orange; eggs are laid in a compact cottony mass.

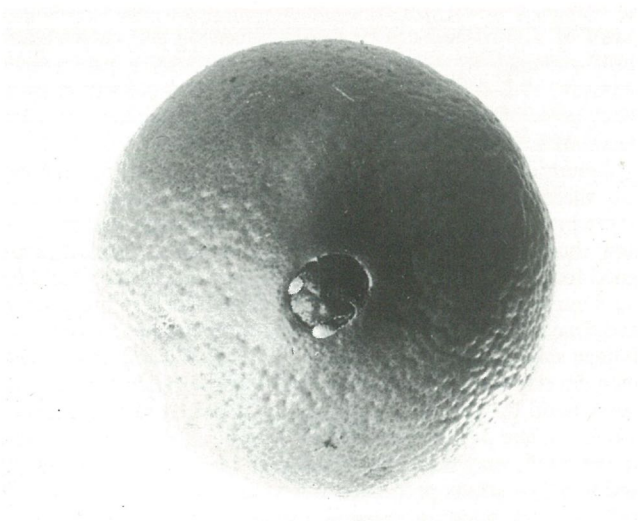
CITROPHILOUS MEALYBUG Anal filaments are about one-third the length of the body; body colour showing in four dark longitudinal dorsal lines; glandular exudate is claret-coloured; eggs are deposited in an irregular cottony sac.

Long-tailed mealybugs have produced about 200 young in two to three weeks, and the other two species have laid about 500 eggs in one to two weeks (Ebeling, 1959). The young mealybugs resemble the adults. The three female nymphal stages each take a few weeks to develop. Males in the early stages are similar to females, but later form cottony cocoons about 3 millimetres long, within which they develop. The adult males are minute two-winged insects with legs and aborted mouthparts which are incapable of feeding.

There are several generations per year, and populations tend to be highest in spring and autumn. The mealybugs feed on foliage, young twigs and fruits, particularly in protected sites such as beneath spider webbing, between fruits in contact and beneath calyx lobes. They move about on the trees and, at times, shelter in tree crotches and beneath loose bark. Long-tailed mealybugs observed on citrus in South Australia moved from the foliage to branches, trunks and soil in spring and a new generation returned to the foliage; this behaviour was not the same on other hosts (Browning, 1959).

Injury Mealybugs suck sap, but the most important damage is due to the production of honeydew on which sooty mould develops and dirties the trees and fruit. If they are in the navels of mature oranges, the sooty mould is not easy to remove by washing before packing.

They settle commonly under the calyx lobes of young fruits. If the fruit falls, the mealybugs are sometimes suspected as being the cause, but they have not been found to be harmful in this way in New South Wales.



Mealybugs on orange navel.

Dispersal Since young mealybugs move about within the tree for much of their life, they can be dispersed by wind and by visiting insects and birds, and on the clothing of orchard workers.

Control measures

NATURAL Mealybugs have many parasites and predators. The most important predators are lacewing larvae and ladybirds, particularly the mealybug ladybird, *Cryptolaemus montrouzieri*. This ladybird, which is black and red and 3.5 millimetres long, lays its yellow eggs singly in the mealybug egg sacs or near clusters of mealybugs. The larvae have long marginal filaments and are covered with white mealy material, so they may be mistaken for mealybugs. They can be recognized by their biting mouthparts and their greater activity. Mealybug populations have been seen to build up after the application of DDT and after the use of strong Bordeaux mixture. Trees in dusty places also carry more mealybugs than similar trees which are free from dust. Ants tend to assist mealybug infestation by discouraging natural enemies. For parasite records see Wilson (1960).

APPLIED If natural enemies are unable to cope with the infestation, spraying with petroleum oil 2 per cent will give fairly satisfactory results. Maldison 0.1 per cent plus petroleum oil 1 per cent can give a high kill of mealybugs, but is more harmful to natural enemies. Both sprays will loosen sooty mould from trees and fruit.

Larva of the mealybug ladybird, *Cryptolaemus montrouzieri*.

Australian citrus whitefly

Orchamoplatus citri

Importance and Distribution This whitefly is a sucking insect which mainly infests the undersides of leaves. It causes no direct injury, but has a nuisance effect by producing honeydew and thus causing the growth of sooty mould. It is considered to be native (Jenkins and Shedley, 1953) and occurs in coastal and inland districts. Inland, it became prevalent first in the Lower Murray district in the early 1950s.

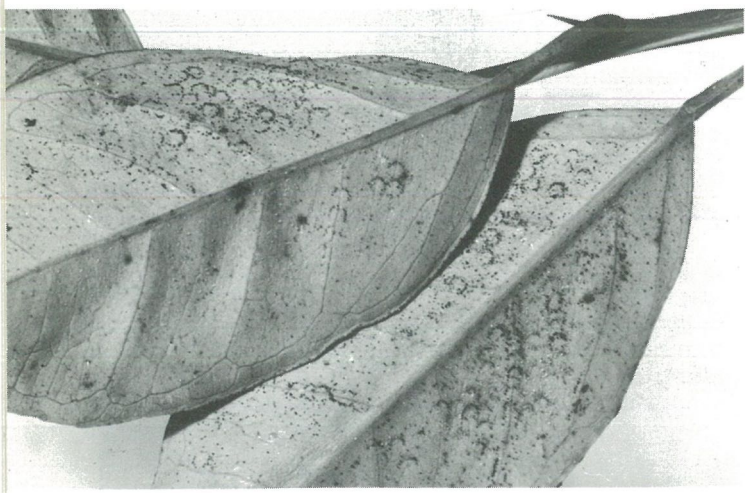
The citrus yellow fly, *Asterobemesia helyi* Dumbleton, is a pest of citrus trees in suburban Sydney, but only in harbourside gardens.

Conditions for Infestation Warm moist weather and the sheltered environment inside a vigorous thickly-foliaged tree appear to be most suitable.

Plants attacked All types of citrus are infested.

Description and Life History The adults are about 2.5 millimetres long. The wings are covered with white powdery wax that rubs off easily. The adults will fly out in swarms if the foliage is disturbed. The adult female places the translucent-yellow narrowly-oval eggs in circular patterns on the undersides of young leaves. The whole area of the egg-laying site appears to have been dusted over with the white powdery wax.

The larvae hatch from the eggs, and settle in groups on the lower surfaces of leaves. At first they are flat and rather similar to soft scale crawlers, and feed and develop beneath a clear varnish-like, protective covering. There are three nymphal stages and a pupal stage before adult development. Several generations occur in a year, but infestation is most obvious in spring and autumn on new foliage growth.



Australian citrus whitefly eggs in circular patterns on undersides of leaves.

Injury Fruits within the tree canopy are made dirty by sooty mould developing on the honeydew that these insects secrete.

Dispersal Whiteflies can be dispersed by wind. Introduction into orchards on new trees at planting is quite possible, as trees are easily infested in nurseries and the immature stages on the undersides of leaves are inconspicuous.

Control measures

NATURAL Ladybirds and lacewing larvae prey on the whitefly.

APPLIED Spraying, as for California red scale control, with petroleum oil or organophosphorus insecticides reduces whitefly infestation. Specific spraying against whitefly could only rarely be warranted.

Black citrus aphid

Toxoptera aurantii and *Toxoptera citricidus*

Importance and Distribution Aphids occur commonly on citrus, and form colonies on tender growth. They feed by sucking sap, but usually cause little direct harm except to nursery and young orchard trees, and sometimes by restricting fruit set of navels. They occur in all areas of New South Wales, but more frequently in coastal districts. *Toxoptera citricidus* is by far the most common citrus-infesting aphid in eastern Australia (Carver, 1978). Occasionally spiraea aphid, *Aphis citricola* Van der Groot, and cowpea aphid, *A. craccivora* Koch, also infest citrus.

Toxoptera citricidus occurs in many countries, but not in the United States of America or north of the Mediterranean. It is of especial interest as the most efficient vector of an important virus disease of citrus, tristeza.

Conditions for Infestation Mild moist conditions with an abundance of sappy new citrus foliage are favourable. Black citrus aphid infestation is more frequent in coastal than in inland districts, which is presumably due to the longer periods of suitable foliage growth and perhaps to the greater numbers of lemon trees producing new growth throughout the warmer parts of the year.

Plants attacked Citrus varieties are the principal hosts, though other plants of the family Rutaceae may be infested.

Description and Life History The adults are either winged or wingless, about 1.5 millimetres long, and black. Winged forms of *T. citricidus* can be distinguished by the wholly black third antennal segment which is succeeded by a pale fourth (Stroyan, 1961). The young of both species are dull red-brown. They grow by a series of moults, and their white cast skins are common amongst the insects in the colonies.

Aphids can be found on citrus foliage for most of the year, but are most abundant in spring and autumn. Small colonies overwinter on young shoot growth inside the trees, and move to new shoots which start to grow in late winter. If conditions are good for shoot growth in the spring, heavy infestations build up by September and October. Natural enemy activity increases at this time. If dry harsh conditions set in, the production of sappy foliage suitable for aphid feeding will stop. Winged adult forms then develop and leave the trees, and the infestation ceases. Colonies build up again during the autumn period of lush growth. The complete development, from the birth of the young nymph to the adult, may take little more than one week. Both winged and wingless adults produce active young, not eggs. As with all aphids, population increase is extremely fast under suitable conditions.

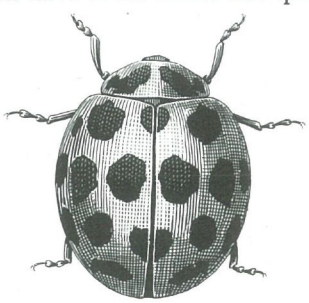
Black citrus aphids.

Injury Shoot growth is deformed because the aphids cause curling of very young leaves and stems. This causes an undesirable set-back in growth of nursery and young orchard trees, and in mature trees recently cut back for rejuvenation. Infestation at blossom stage can cause reduced fruit setting, mainly in navels. Lemons and Valencias are not so much affected in this way. Aphids secrete honeydew, thus causing sooty mould on foliage and fruit.

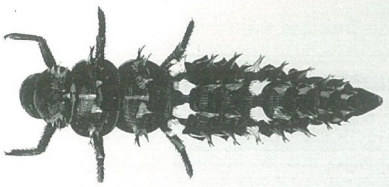
Dispersal Winged aphids can be transported by wind over long distances (Hughes *et al*, 1965).

Control measures

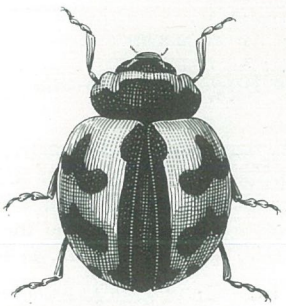
NATURAL Many predators – ladybird adults and larvae, and hover fly and lacewing larvae – and some parasites depress aphid populations. Birds also play a part in aphid control. The most effective predators are the ladybirds, for example, common spotted ladybird, *Harmonia conformis* (Boisduval), transverse ladybird, *Coccinella repanda* Thunberg, variable ladybird, *Coelophora inaequalis* (Fabricius) and *Platyomus lividigaster* Mulsant. *P. lividigaster*, a small blue-black beetle, with lemon yellow head and prothorax, can anticipate black citrus aphid activity. It deposits its yellow spindle-shaped eggs on the foliage in summer, a week or so before there are any signs of new shoots or of aphids. Its larva is red-brown and spiny.



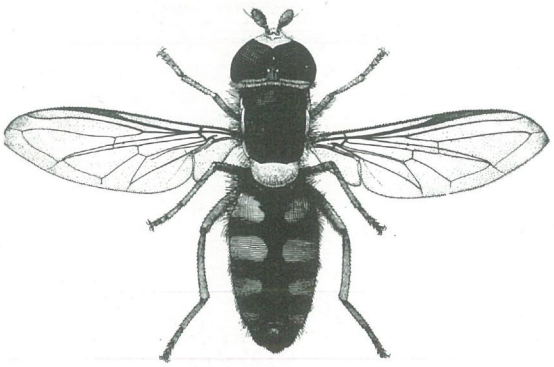
The common spotted ladybird, *Harmonia conformis*. (Length about 7 mm)



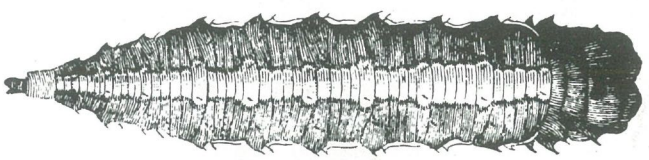
Larva of the common spotted ladybird, *Harmonia conformis*.



The transverse ladybird, *Coccinella repanda*. (Length about 5 mm)



A hover fly adult. (Length about 12 mm)



A hover fly larva. (Length, when fully developed, about 12 mm)

APPLIED Systemic organophorphorus insecticides, such as demeton-S-methyl 0.02 per cent or dimethoate 0.02 per cent, or the contact insecticide maldison 0.05 per cent, are suitable sprays. They should not be applied in mixture with Bordeaux spray. Dimethoate should not be used on Seville orange, kumquat and Meyer lemon, as it may injure these trees.

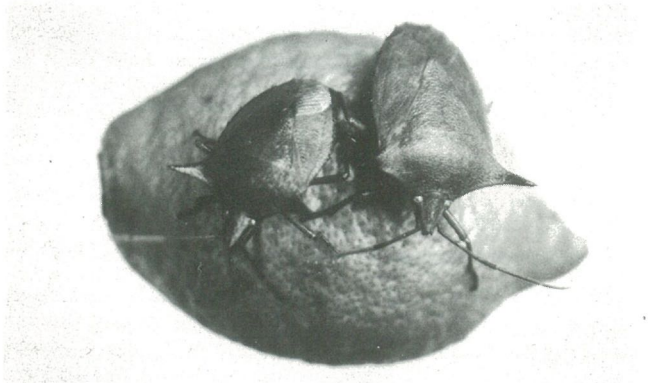
Spined citrus bug *Biprorulus bibax*

Importance and Distribution This native insect is restricted to Queensland and New South Wales. It occurs in coastal and north-western inland areas of New South Wales and was recorded as a pest of citrus in 1898, under the name *Rhyncocoris* sp., by Allen *et al.* The bugs feed on the fruit of citrus, and damage it or cause it to fall. A small number of bugs on a tree can cause a great deal of fruit loss. Home-garden trees are often severely affected, but in commercial orchards it is only infrequently a pest of importance. The records of more important orchard infestations have been on lemons and mandarins in lowland coastal districts and in the Hawkesbury Valley.

Conditions for Infestation The distribution of spined citrus bug suggests that moderate humidity in summer is required. Culturing the bug in the laboratory has shown that a constant supply of moisture is essential for the hatching of eggs and the survival of the first nymphs (Summerville, 1931).

Plants attacked The native hosts are the desert lime, *Eremocitrus glauca*, and the finger lime, *Microcitrus australasica*. All cultivated citrus appear to be susceptible, but lemon, mandarin, lime, kumquat and trifoliata, *Poncirus trifoliata*, are preferred hosts.

Description and Life History There are seven stages – the egg, five nymphal instars and the adult. The adult is about 20 millimetres long, lemon-green on top and slightly paler underneath, with a stout sharp spine on each shoulder of the thorax. It is about 16 millimetres wide from spine tip to spine tip. The eggs are almost globular and slightly over 1 millimetre in diameter; they are white at first, then red with dark marks appearing within as the embryo develops. First- and second-stage nymphs are marked in yellow, green, black and orange. By the time the nymph reaches the fifth stage it is green, mottled with black, and has distinct wing-pads but no shoulder spines.



Spined citrus bug adults. (Length of adult about 20 mm)

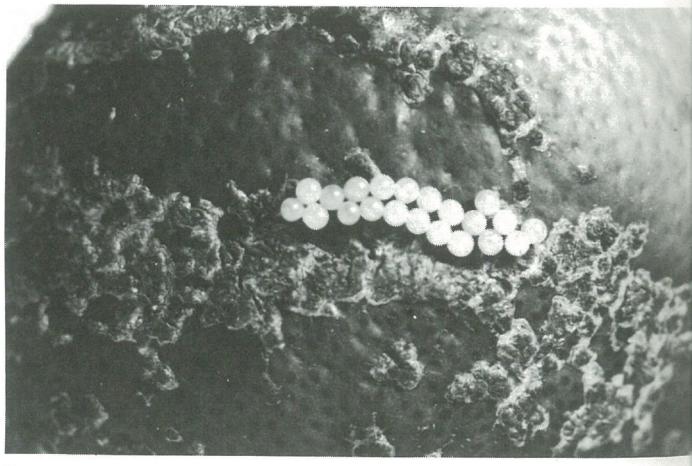
Spined citrus bug – young stages.

The bugs overwinter in the adult stage, by sheltering within the trees from about June to late August. In September they mate and feed, and later in the month they lay eggs, which hatch in about two weeks. In warmer weather later in the year, hatching may take only three days. The eggs are usually laid on leaves or fruits in batches of about twenty eggs in single or double rows.

First-instar nymphs cluster around the egg mass and do not feed. After several days they moult, and the second-stage nymphs scatter and feed. The fourth- and fifth-instar periods are much longer than the earlier instar periods. The time from egg to adult is about six weeks in warm weather, and there may be four generations per year.

The adult females can lay eggs when about fourteen days old, and may lay about 100 eggs over several weeks. Adult bugs are active and fly strongly, although in winter they rest in the trees, often in groups, and do not fly unless disturbed.

Fourth- and fifth-stage nymphs and adults can eject an evil-smelling liquid that stains yellow and irritates tender skin, but it is not as objectionable as that from the bronze orange bug.



Eggs of spined citrus bug.

Injury The fruit is attacked at all stages. Immature lemons under 40 millimetres long, and oranges and mandarins which are not fully mature when attacked, usually turn yellow and fall. Larger immature lemons do not fall, but go yellow at the point of feeding and the yellowing spreads over the fruit. Ripe lemons will show no outward sign of damage, but if severely attacked, they will be lighter in weight than unharmed fruit and dried out internally to some degree. Damaged fruits have dry segments, often with internal gumming, and there is brown marking through the skin of the fruit along the entry line of the bug's feeding organ. Another typical feature of bug attack is the darkening and shrivelling of the seeds, and this can be important on trifoliata and other varieties grown for seed production in citrus propagation programmes.

When bugs attack ripe oranges, large lesions may surround the puncture point due to invasion by fungi.

The drying out of lemons is not always due to bug attack. It can be caused by a physiological condition induced under water stress, and seen mainly in winter. Bug injury is most prevalent in summer and autumn.

Lemons damaged by spined citrus bug.

Dispersal The bugs fly strongly, probably for considerable distances. In Queensland, bugs may migrate from the native desert limes of inland areas to the finger limes which grow in coastal districts (Summerville, 1931).

Control measures

NATURAL Several wasps parasitize the eggs, sometimes very frequently. In New South Wales, the best known is *Hadronotus* sp. Predators like the assassin bug, *Pristhesancus papuensis* Stål, prey on the pest bugs.

APPLIED Dimethoate 0.03 per cent, or maldison 0.1 per cent, or diazinon 0.05 per cent, all in petroleum oil 1 per cent can be used for spraying. Dimethoate, maldison or diazinon should not be applied with Bordeaux spray. Spraying should be done at any time of the year if more bugs are present than can be dealt with by hand picking. Dimethoate should not be used on Seville orange, kumquat or Meyer lemon, as it can injure these trees.

Green vegetable bug *Nezara viridula*

This introduced pest was once an important pest of vegetables and lucerne, but is much less abundant now. It was commonly found feeding on young shoots of citrus in September, but this was of little importance. Occasionally in autumn there was severe injury to citrus trees in inland areas after neighbouring lucerne fields were mown. The bugs would migrate to the citrus and cause a severe fruit-fall.

It is more fully described on page 232 under Bean Pests.

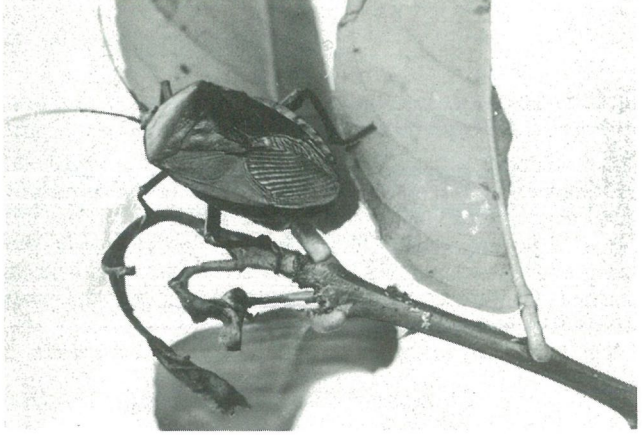
Bronze orange bug *Musgraveia sulciventris*

Importance and Distribution This native insect has been known to attack cultivated citrus for many years, and was recorded as causing shoot damage and fruit loss at Lismore by Olliff (1892). It is now a well-known inhabitant of citrus trees in coastal, upper Hunter and some North-Western Slopes districts. In coastal areas it can cause a heavy fall of young fruits and severe tree injury. The worst problems have been in North Coast orchards. In the Central Coast area the bugs have spread rapidly since first recorded there in the early 1940s (Hely, 1964), but commercial orchards in the area have had only infrequent severe infestations. The bugs are notable for their foul odour, and their corrosive secretions burn the foliage.

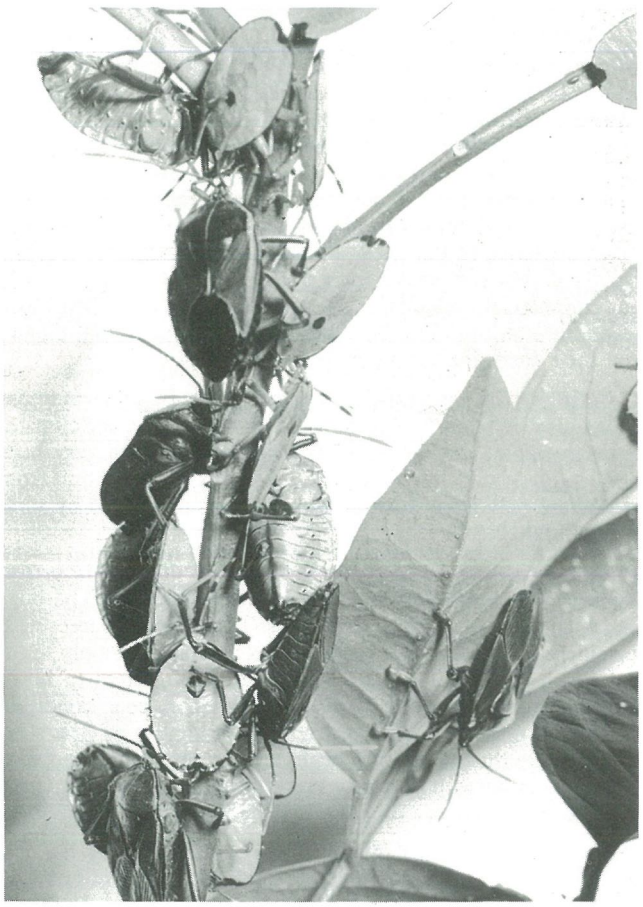
Conditions for Infestation Bronze orange bug thrives under subtropical to warm temperate conditions, but hot dry climates are unsuitable. The bugs are affected adversely by very high temperatures with low humidities. Records of infestation from inland are only from districts with climates influenced by summer rainfall.

Plants attacked The Australian round lime, *Microcitrus australis*, has been seen as a host at Murwillumbah. The bugs attack all varieties of cultivated citrus. Thick vigorous trees with succulent foliage are most readily infested, and are mainly selected by the bugs for egg-laying. Rough lemon trees in home gardens are often infested severely. Trees in poor condition commonly escape attack; trees reduced in vitality by heavy infestation are thus sometimes neglected for egg-laying, and start the next season with very few bugs. No hosts other than citrus are known.

Description and Life History Bronze orange bug has five nymphal stages. The eggs are laid on the undersides of leaves in batches, usually consisting of fourteen eggs, arranged in four rows. One female lays several batches. This happens from midsummer to early April; the greatest number are deposited in February. The eggs are glossy, green, spherical, about 3 millimetres in diameter, and hatch in eight to fourteen days. The light green first-stage nymphs remain near the egg-shells and do not feed. After a few days they moult to the second stage in which they overwinter. The second-stage nymphs are about 6 millimetres long, pale green or yellow and almost transparent. They are thin and flat and often called the 'tissue paper' stage, and remain inactive on the undersides of leaves until spring. It is very difficult to see them, but a 'buggy' odour is obvious when the leaves are disturbed. Also, the empty egg-shells remain on the tree for a long time and are fairly obvious.



Bronze orange bug and damaged leaf shoot. (Length of adult about 25 mm)



Bronze orange bug adults and fourth- and fifth-stage nymphs.

When growth of the tree begins in spring, the second-stage bugs become active and, in about late August, begin to feed on young succulent new leaves. They increase in size and, three or four weeks after the start of feeding, moult to the third stage. The third, fourth and fifth stages occupy about three weeks each. The third-stage nymph is green and may be margined with black. The fourth stage is green, pink or salmon-coloured, and has wing buds. The fifth stage, which appears during November, is green-grey, salmon or pink and has large wing buds. It feeds voraciously and is very aggressive in discharging a foul-smelling liquid which can burn tender skin.

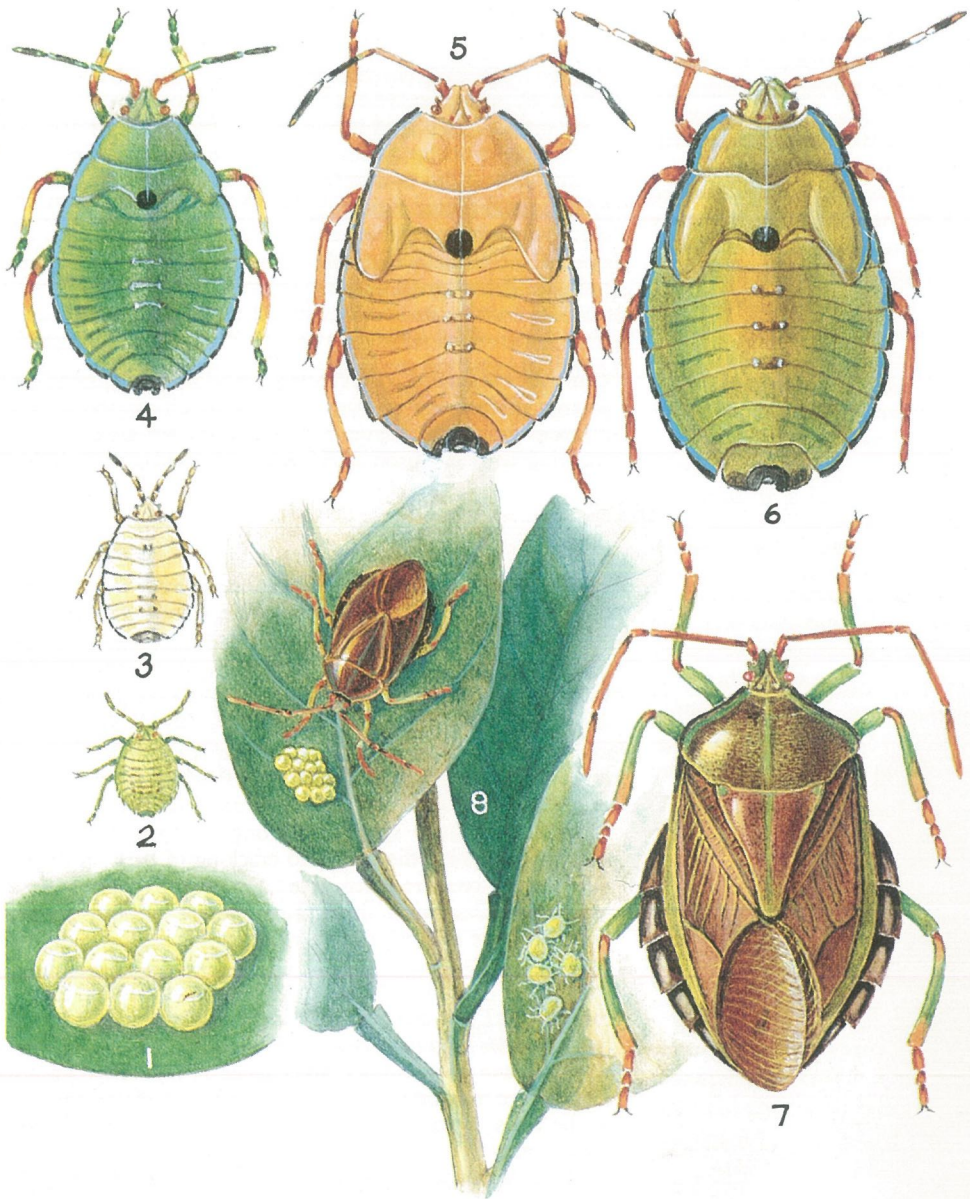
The adult stage is reached in late November December, and the adults are present on the trees throughout the summer. Most of them will have deposited eggs and died by the middle of April. They are approximately 25 millimetres long, stoutly built, and bronze-coloured at first but becoming nearly black as they age. The legs and portions of the antennae are red, as also is the upper surface of the body beneath the wings. Often groups of about six feed together on shoot growth and fruit stalks. When young growth is scarce they may not feed, but they will begin again when the summer growth cycle begins. Soon after they start to feed again, mating and egg-laying occur. This dependence of the adult on young shoot growth for feeding before egg-laying explains their attraction to vigorous trees.

During summer the adults sometimes cluster on the trees in masses which may be as big as a football. If disturbed, the bugs fly around like angry bees. The adults are very active and, like the fifth-stage nymphs, readily discharge a liquid which has a most obnoxious odour and can stain and burn human skin and eyes. The adults can squirt it for some 60 centimetres from glands in the sides of the thorax. The liquid has been described fully by Waterhouse *et al* (1961). The bugs also excrete corrosive liquid from the anus.

Injury Damaging feeding by the bugs is almost restricted to the spring and early summer, when they suck young shoot growth and the stalks of flowers and young fruits. The shoots die, and the flowers and fruits fall. As the supply of sappy growth is destroyed, the bugs feed on the stalks of older leaves which then fall. Further damage can result from the caustic liquid produced by the bugs; where it falls on leaves or fruit, brown spots of dead tissue appear. This will sometimes cause leaf-fall. Trees that have suffered a severe attack take on an unthrifty appearance and carry a sparse crop. When relieved of bugs they will recover under good conditions of nutrition, but an out-of-season cropping habit may follow.

The damage from summer feeding of adults is of no importance.

Bronze orange bug egg-shells and second-stage nymphs on undersides of leaves.



Bronze orange bug
Musgraveia sulciventris

1 Group of eggs; **2** first-stage nymph; **3** second ('tissue paper') stage; **4** third stage; **5** fourth stage; **6** fifth (pre-adult) stage, showing well-developed wing buds; **7** adult bug; all enlarged 2.5 times. **8** Citrus leaves with eggs, first-stage nymphs and adult bug; actual size.

Dispersal The adults are strong fliers and capable of migrating over long distances between orchards. In North Coast districts isolated orchards can be infested by bugs bred on seedling citrus trees growing in bush areas.

Control measures

NATURAL The bronze orange bug is scarcely affected by cold in winter. The 1943 winter at Moorland was most severe, yet the infestation in the following spring was exceptionally heavy. High temperatures, especially with low humidities, distress the bugs, and they will crawl down the branches and, at about 41°C, cluster around the butts at ground level. Orchardists sometimes spray them there or destroy them by hand. At even higher temperatures many bugs will die.

Birds feed on the bugs in spring and summer. The assassin bug, *Pristhesancus papuensis*, causes high mortality of all stages. This is a long-lived bug – individuals are active for eight to eleven months (Noble, 1936b). They are common at Moorland but are not seen at Gosford. When taken to Gosford in 1950 they did not survive.

Egg parasites of the bronze orange bug are uncommon.

APPLIED Destroying individual bugs, by dislodging them on to the ground and crushing them or into a tin of sump oil or kerosine, is useful for minor infestations, especially as there is only one generation per year.

Bugs are easily detected by their odour even in winter, so infested trees can be noted for later attention. Spraying should

be carried out as early as possible in spring, or even in winter, before the bugs can do any damage.

Control of the young bugs in winter was first demonstrated in Queensland, by Summerville (1935), using resin soda spray. Next came the discovery that spraying in winter with soft soap 2.0 to 2.5 per cent gave spectacular results. In one winter, a district-wide effort with soft soap at Moorland cleaned out bronze orange bug for a number of seasons (Hely, 1944).

Many modern sprays are highly toxic to the bugs, but are limited in usefulness if they cannot be mixed with the Bordeaux spray which is commonly used in spring. Dimethoate 0.03 per cent or maldison 0.1 per cent, with 1 per cent petroleum oil, kill the bugs but should not be used with Bordeaux. Dimethoate should not be used on Seville orange, kumquat or Meyer lemon, as it can injure these trees.

Crusader bug *Mictis profana*

Importance and Distribution These native bugs feed on many native wattles, acacias and cassias, also on grapes and ornamentals, as well as on citrus. They cause a moderate amount of killing of new shoot growth, and this may be important on young trees. They mainly occur in inland districts as pests of citrus.

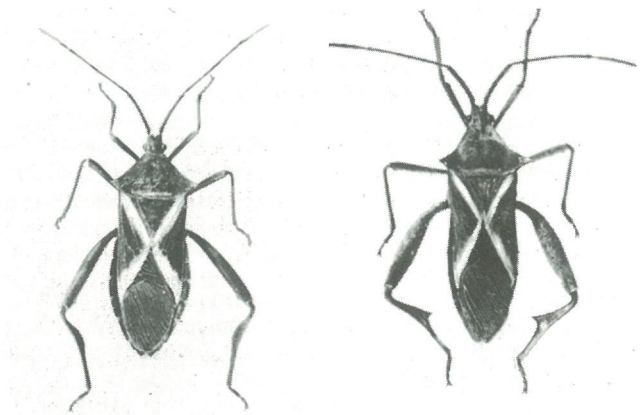
Description and Life History The adult bug is 20 to 25 millimetres long, 7 to 10 millimetres wide, and brown with a clear St Andrew's cross in yellow on its back. The legs are long. The shoulders of the thorax project into short spines in the fourth- and fifth-instar nymphs and adults.

The adults overwinter and then attack new growth in the spring. There are several generations per year.

Eggs are laid in rows or clusters covered thinly with a gummy substance. They are laid on leaves, twigs, or fruit and sometimes in debris on the soil. The first-stage nymph has a red abdomen. Later instars have a pair of orange spots in the middle of the upper surface of the abdomen. The wing buds in the last two instars are marked with orange.

Injury Damage is confined to young growth. Both growth shoots and flowering shoots are attacked, and wilt, blacken and die.

Control measures Spraying with dimethoate or maldison plus oil as for bronze orange bug, will kill crusader bugs.



Crusader bugs: female at left and male at right. (Length 20 to 25 mm)

Citrus blossom bug *Austropeplus* sp.

This is an undetermined species which can reduce blossom production on coastal citrus trees (Gellatley, 1967). It is probably native to Australia. The adult is approximately 5 millimetres long, mainly green on the underside of the body and dark above, with yellow on the thorax and red and black wing markings. Young and adults feed on citrus shoot growth and, after their attack, small flower shoots (up to 12 millimetres long) wilt and die. Even light bug infestations in September can destroy a great deal of the total blossom shoot on the trees. This is probably unimportant on trees that are beginning a heavy blossom production, but it can severely curtail blossoming and, therefore, fruit set on trees which are about to blossom only lightly.

Control measures Preventing crop loss will depend on the prompt observation of bugs on trees which are initiating light blossom growth in September. The bugs are killed readily by spraying with maldison 0.05 per cent or carbaryl 0.1 per cent.

Rutherglen bug *Nysius vinitor*

These small native bugs sometimes swarm on young citrus trees and do considerable damage in a short time. This is most likely in spring when weeds, on which the bug population has built up, dry off and the bugs move to the trees. When young orchards are cultivated in spring and the tree squares are left weedy, the bugs are concentrated in these squares. When the weeds die the bugs move on to the trees, as immature stages as well as adults, sometimes in huge swarms. Wilting and leaf-fall occur, and there may be twig die-back and cracking of bark on the stems. The young trees are often killed.

Early cultivation of the squares, before the bug population becomes large and before the weed growth begins to dry, is the best way to avoid attack. If an attack does develop, a thorough spraying of the infested trees and weed growth around them with maldison 0.1 per cent will kill the bugs.

Sometimes migrating swarms of adult Rutherglen bugs invade citrus trees in mid-summer, and cluster on the foliage for a short time before moving on. This type of visit seems to do no harm to the trees. Frequently this swarming is on trees infested by black scale.

More details will be found on page 163 under Grape Pests.

Green plant-hopper *Siphanta acuta*

This insect is found commonly in late spring on coastal citrus trees, usually on very young foliage. It sucks sap but appears to cause no harm.

The adult is apple green, and holds its wings when at rest in a roof-like fashion. Viewed from the side it is triangular, with the head at one end of the base of the triangle. The body is about 8 millimetres long.

The young stages resemble mealybugs but, with increasing age, they move actively and skip for short distances when disturbed.

The egg mass is circular and convex above, and is at first white but becomes dark near hatching.

Passionvine hopper *Scolypopa australis*

These insects are commonly seen on coastal citrus trees in spring, occasionally in very large numbers. Although as many as five or six nymphs or adults have been seen on almost every fruit stalk, infested trees have not carried less fruit at harvest than uninfested trees. There is a certain amount of honeydew production with the consequent growth of sooty mould.

Passionvine hopper is a native with a wide variety of host plants, both cultivated and wild. The adults are brown and about 8 millimetres long, with mottled wings, and are somewhat similar in appearance to moths. They can both hop and fly. The eggs are inserted in small twigs in rows. The young nymphs are squat and brownish green, with white woolly filaments at the tip of the abdomen. Like the adults, they jump quickly when disturbed.

Further information on this pest is given on page 189 under Passionfruit Pests.

Leafhoppers Cicadellidae

Green or grey-brown leafhoppers about 5 millimetres long, are often numerous on summer grass around the skirts of coastal citrus trees in autumn. Their presence has been associated with skin injury spots of the oleocellosis type on oranges which are starting to colour in autumn. The possibility of injury from this cause would be prevented by mowing or other cultural practices to prevent excessive grass growth around the trees.

ORTHOPTERA

Inland katydid *Caedicia simplex*
Citrus katydid *Caedicia strenua*

Importance and Distribution Both species are native insects belonging to the family Tettigoniidae, the long-horned grasshoppers. *Caedicia simplex* occurs in inland areas and can be an important pest of stone fruits. *C. strenua* is found in coastal districts. The life histories, habits and injuries to citrus are similar for both species.

The main damage to citrus occurs when the immature stages of the insects gnaw the rind of young fruit, and blemish it severely. Feeding on leaves is unimportant.

Conditions for Infestation Katydids are suited by moist conditions and vigorous trees. Injury is less likely on trees in poor health. It is probable that adults select vigorous trees for their feeding and mating in late summer, and then oviposit beneath them. Commonly, individual trees may carry large populations of nymphs in spring while nearby trees may have none.

Plants attacked The natural hosts of these insects are not known. Among citrus varieties, katydids show a preference for thickly-foliaged trees. Navels and Valencias are commonly attacked but lemons are not much affected. Blackberries are a common source of food for the citrus katydid.

Description and Life History Katydids are angular flat-sided insects which have long thread-like antennae and strong hind legs for jumping. Adult males make a metallic clicking chirrup sound in dull weather and in the early evening, during summer and early autumn.

CITRUS KATYDID The adult is grass green and approximately 4.5 centimetres long from the head to the tip of the folded wings. The abdomen is rounded, with purple sides. The forewings are narrow and opaque, with a black band on the posterior edge. The hindwings are fan-like, transparent and very pale green. The female is more plump than the male and has a short soft inconspicuous upwardly-curved ovipositor.

INLAND KATYDID The adult is slightly larger than the citrus katydid. It is pale green, with a yellow band on the thorax and the anterior margins of the forewings, and yellow on the inner sides of the hind legs. The female has a short horny upwardly-curved ovipositor.

Newly-hatched nymphs are fragile-looking, and are somewhat similar in appearance to ants except for the long antennae. At first they are pale green, but they soon become speckled with brown or black markings. The later-stage nymphs are mainly green with some brown markings and, in the case of the citrus katydid, purple on the sides of the abdomen.

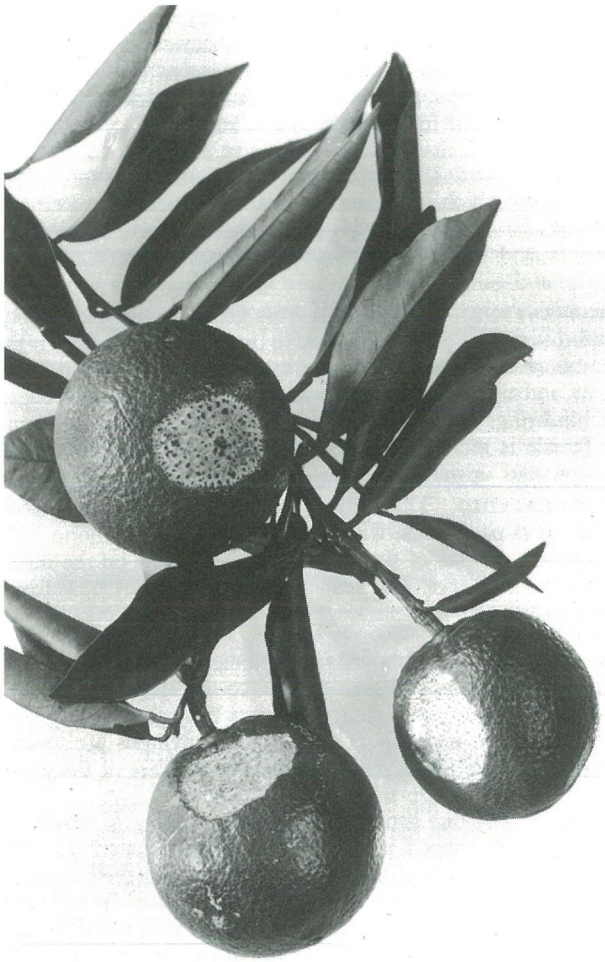
There is only one generation per year. The eggs, which are oval or kidney-shaped in outline and approximately 5 millimetres long and 1.5 millimetres wide, are cemented together with soil in masses of about twelve eggs, and usually arranged in parallel rows. They are laid from January to April at soil-surface level beneath the tree, but some may be in moss in the fork of the tree. The egg masses are extremely difficult to see, as they are exactly like small clods. In a laboratory study, the maximum number of eggs dissected from a single female was 64, but caged females laid no more than two egg masses.

The earliest recorded hatching is in September. As the young need succulent leaf tissue, it is likely that late-hatching nymphs would die from a lack of suitable food. There are five instars, and it has been shown for the citrus katydid that each requires sixteen to twenty days for development. Wing buds appear after the third moult.

The adults appear in December and January and nibble foliage but, except in the early adult stage, they are not voracious feeders. They do no important damage and rarely feed on citrus fruit, except when small second-crop fruits are available.

Injury The first-stage nymphs feed on the youngest foliage, and usually eat the upper surface of the leaf down to the lower epidermis – sometimes eating right through and sometimes leaving patches untouched. This gives the leaves a lace-like appearance. The nymphs normally ignore the leaf edges. All immature stages can feed on newly-set fruits, and later-stage nymphs gouge deeply into the rind leaving chalk white scars. As the new fruits grow they become unattractive and fruits which are larger than a walnut are not attacked. The damaged fruits remain on the tree and mature normally. As they grow the scars change to a leaden-colour and flatten out.

Dispersal The adults are capable of strong flight.



Deep injuries by katydids to newly-set citrus fruits flatten out as the fruits grow.

Control measures

NATURAL Predatory flies, wasps and bugs probably take some toll of katydids, but birds are thought to be the most important natural enemies.

APPLIED Lindane 0.03 per cent and maldison 0.075 per cent are effective sprays. Lindane may taint fruit and should not be used near harvest. As the insects are often numerous on individual trees, hand picking is often practicable as soon as evidence of their damage has been observed.

Two other katydids may be found on citrus. Adult *C. olivacea* are often seen in spring on coastal citrus trees. They nibble tender foliage but do no important damage. The green gum tree katydid, *Torbia perficita* Walker, sometimes oviposits on twigs of coastal citrus trees. The eggs are grey-brown, kidney-shaped and approximately 5 millimetres long, and are usually laid in a double row. The insect is not a pest of citrus, but has been reared in the laboratory on *Eucalyptus* spp. and *Angophora* sp. (Mosse-Robinson and Hely, 1957).

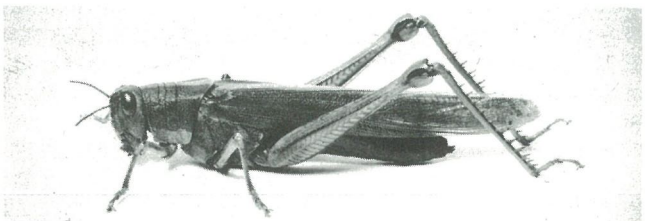
Grasshoppers and locusts:

Giant grasshopper *Valanga irregularis*
Spur-throated locust *Austracris guttulosa*
Australian plague locust *Chortoicetes terminifera*

In north-western areas of New South Wales the giant grasshopper, *Valanga irregularis*, sometimes causes severe damage to foliage and fruit of citrus due to the voracious feeding of nymphs or adults in autumn and winter. These insects are up to 9 centimetres long in the adult stage, but may be difficult to see because of their colour, which is green-brown as adults and pale green as nymphs.

Adults of the spur-throated locust, *Austracris guttulosa*, may sometimes damage citrus foliage in north-western areas in autumn and winter. The adult is up to 7.5 centimetres long and purple-brown, and has a spur on the underside of the neck.

The Australian plague locust, *Chortoicetes terminifera*, breeds up to very large numbers in western areas in some seasons. When this happens, flying swarms may invade citrus orchards and defoliate trees seriously. They prefer trees lacking in vigour, such as those suffering from the effects of root-rot or saline soil. The locusts are 4 centimetres long from the front of the head to the tips of the folded wings, and are brown, grey or green. The forewings are mottled with dark spots or blotched, and the transparent hindwings have a large black spot at the tip. The shanks of the hind legs are scarlet.



Giant grasshopper. (Length up to 9 cm)

Control measures Spraying with maldison 0.1 per cent should be effective against any of these grasshoppers and locusts.

ARACHNIDA ACARINA

Citrus bud mite *Eriophyes sheldoni*

Importance and Distribution This tiny eriophyid mite distorts growth of shoots and sometimes of fruit. It was first reported as a pest of lemons in California (Boyce and Maxwell, 1938; Boyce and Korsmeier, 1941). Similar mites were then found at Gosford (Hely, 1939) and it was realized that the damage had existed in New South Wales for some years. Since then the pest has been recorded in most citrus areas of the world.

Evidence that its injuries had been figured in Italy in 1646 was given by Jeppson and de Pietri-Tonelli (1953). In New South Wales it has been important mainly for its damage to nursery trees and Eureka lemon.

Conditions for Infestation Citrus bud mite occurs in inland as well as coastal areas. It is more important in coastal districts, which indicates that temperate conditions with fairly high humidity are the most suitable.

Plants attacked Citrus is the only known host. All varieties may be infested but lemons are preferred, especially Eureka, followed by Washington navel. Homosassa and Siletta oranges are susceptible, but Valencias are hardly affected.

Description and Life History Adult mites are approximately 0.17 millimetres long, and sausage-shaped with two pairs of legs near the head end. They are cream or pale pink. In a laboratory test, adult mites survived on the host for a month.

Each female deposits about 50 eggs, by placing them singly on the tender tissue where the mites are feeding. The eggs are globular, white and relatively large. They are present at all times of the year, but are most abundant in late winter and spring. The period of time from egg to adult is ten to fifteen days in summer and autumn, but longer in winter. There are four immature stages of the mites – two mobile feeding stages and two quiescent moult stages.

Injury Citrus bud mites develop mainly on tender tissue within leaf axil buds or on tiny new shoots. They may be found also between the bud and the shoot or leaf stalk, within flower buds, beneath the calyx lobes of fruit, and sometimes where two young fruits touch. They are most abundant on recent shoot growth; on older wood, the buds are small and mites will penetrate deeply into their centres.

Where infestations are heavy there may be as many as 100 mites in a single bud. Bud scales are often blackened by the mites' feeding and buds may be destroyed. Around damaged buds, small secondary buds may develop and be damaged in turn or produce weak spindly shoots. Growth from infested buds may be flattened and twisted. Growth distortion is most pronounced on vigorous trees. Leaves are often deformed, and small cupped leaves are common.

Probably the most characteristic feature of bud mite infestation is the rosetting or bunching of leaves at the apex of the shoot. Deformity of flowers occurs at times, especially on lemons, and this can result in grotesquely-shaped fruit.

Bud mite injury on non-vigorous trees is sometimes confused with minor element-deficiency symptoms. In field identification, the symptoms of bud mite injury are the rosetting of leaves at the tips of twigs and the variations in shape of leaves, especially irregular margins. Bud mite does not cause colour patterns in the leaves; foliage, fruits and flowers are normal in colour and texture. No gum-staining occurs, nor is there die-back of twigs or leaf-fall. When nursery trees are infested, the proper development of the young tree is impaired.

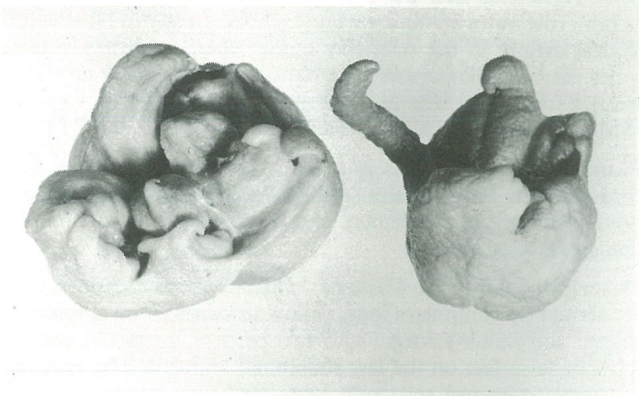
Dispersal Dispersal is mostly by infested nursery trees which have received mites from the use of infested budwood. There may also be some spread of mites by wind or by birds or insects visiting trees, but this is probably limited as the mites do not remain in exposed situations for long.

Control measures

NATURAL Little is known of the mites' natural enemies.

Infestation can be eliminated by very high temperatures. In a severe heat wave at Gosford in 1939, bud mites on trees were not affected by shade temperatures up to 44.4°C, but there was almost complete mortality of all stages after a day with temperatures up to 48°C, and low humidity.

Lemon foliage bunched and distorted by citrus bud mite.



Lemons deformed by citrus bud mite.

Frosty weather, even when quite severe, does not seem to harm bud mites.

APPLIED Lime-sulphur or dispersible sulphur spray provides satisfactory control of bud mite. Best results follow autumn or winter treatment, as this allows normal development of shoots and blossoms in the spring. Dispersible sulphur can be applied in mixture with Bordeaux spray which is sometimes used at that time for disease control.

Lime-sulphur is used at 0.4 per cent polysulphides content plus non-ionic surfactant (10 millilitres per 100 litres). Dispersible sulphur is used at 0.3 per cent.

Spraying citrus trunks and main limbs in winter with strong lime-sulphur, or with dispersible sulphur, is used for control of white louse scale in coastal orchards. Full coverage spraying of the trees with these sprays will also control bud mite. For this the lime-sulphur is used at 1.4 per cent polysulphides, with non-ionic surfactant (20 millilitres per 100 litres) in late June or July. Dispersible sulphur is used at 0.4 per cent.

Lime-sulphur spraying always involves some risk of leaf- or fruit-fall, especially on trees sprayed earlier in the season with Bordeaux mixture.

Petroleum oil at 1 in 50 dilution, in summer, gives a temporary measure of control of bud mite.

Citrus rust mite *Phyllocoptruta oleivora*
Brown citrus rust mite *Tegolophus australis*

Importance and Distribution *Phyllocoptruta oleivora* occurs in most citrus-growing countries, especially in subtropical areas such as Florida. *Tegolophus australis* has been recorded only in New South Wales and Queensland. These eriophyid mites feed on the surface of the young green fruits, and cause blemishing which shows prominently when the fruits colour. In New South Wales, rust mites occur commonly in coastal areas and occasionally in inland orchards, but they are not generally important in this area.

Rust mite of citrus has been known here since the nineteenth century, often under the name 'maori mite', and was mentioned by Olliff (1891). From 1935, it was recognized that the rust mite commonly seen on citrus in coastal New South Wales differed from *Phyllocoptruta oleivora*, and it was described by Keifer (1964) as *Tegolophus australis*. The first positive record of *Phyllocoptruta oleivora* was in 1954 at Newcastle, and the mite recorded previously in New South Wales as *P. oleivora* may have been *Tegolophus australis*.

Both rust mites are now encountered frequently in New South Wales, mainly in the relatively humid coastal districts. Sometimes rust mite damage is important in wet summers in north-western districts, such as Narromine, but generally they are hardly significant in hot dry areas.

Plants attacked Citrus is the sole host for both mites. Records in New South Wales suggest that *Phyllocoptruta oleivora* prefers grapefruit and lemon, and *Tegolophus australis* prefers orange and mandarin.

Description and Life History *Phyllocoptruta oleivora* adults are about 0.15 millimetre long, yellow to yellow-brown, spindle-shaped and rather slender, with two pairs of legs and a pair of lobes or false feet on the last abdominal segment. The eggs are spherical, pale and relatively large, and are deposited singly where the mites are feeding. Up to 29 eggs per female have been observed and these hatch in about three days in summer (Ebeling, 1950). There is a larval and a nymphal stage and the life cycle from egg to adult can be as short as seven to ten days. There are many generations through summer-autumn and development continues in winter and spring, but at a slower rate.

Reproduction had been considered to be parthenogenetic, but males are involved in reproduction and fertilized females lay eggs which produce both sexes, whereas unfertilized females produce only males (Swirski and Amitai, 1959).

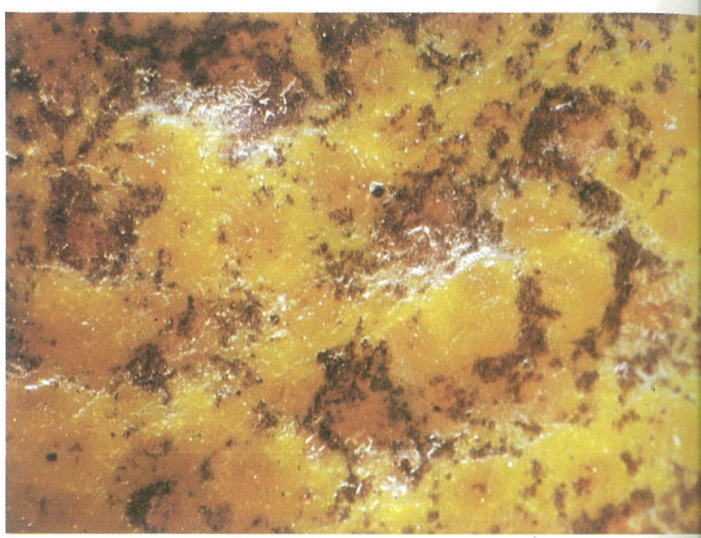
Phyllocoptruta oleivora infests the sheltered surface of fruits on the outside of the tree and the whole surface of fruits inside the tree canopy. It is found also on the lower sides of leaves and on very young shoots. A noticeable increase in numbers of this mite can arise in spring.

Tegolophus australis adults are about 0.18 millimetre long, light to dark brown, comparatively broad and strongly wedge-shaped. The immature stages are lighter in colour, and slimmer. The eggs are disc-shaped and transparent and are placed in the depressions on fruit and leaf surfaces. *T. australis* infests fruit surfaces which are fully exposed to light, the upper sides of leaves, and sometimes the green bark of twigs. It does not favour very young tissue. The mites are rarely seen in large numbers before mid-December and do most damage in late summer.

Injury Both mites blemish citrus by feeding in huge numbers on the green immature fruits. On heavily infested young fruit, the mites and their cast skins can be seen as a dust-like layer on the fruit surface. Blemishing becomes obvious as the fruit colours, and, even after infestation has ceased, the fruit deteriorates in appearance while it remains on the tree.

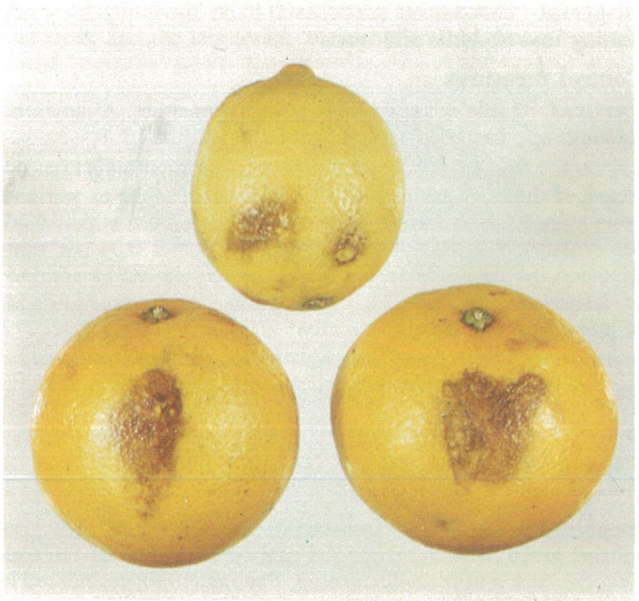
Blemishing by *Phyllocoptruta oleivora* is characterized, as the fruit colours, by extensive brown to lead-coloured areas on the sheltered part or on the whole surface of the fruit. Sometimes there is a purple tinge of colour, and the blemish usually has a 'sharkskin' roughness.

Blemishing by *Tegolophus australis* is seen, as the fruit colours, as extensive smooth dark brown areas on the exposed part of the fruit surface, which look as if they had been polished with dark tan. The margins of the damaged areas are indistinct, whereas a fairly similar blemish by melanose fungus disease has distinct margins. Fruit-blemishing by *T. australis* has been seen most commonly in sheltered situations near buildings and windbreaks. Heavy blemishing of several fruits immobilized by wire netting has been seen, while adjacent free-hanging fruits remained undamaged.

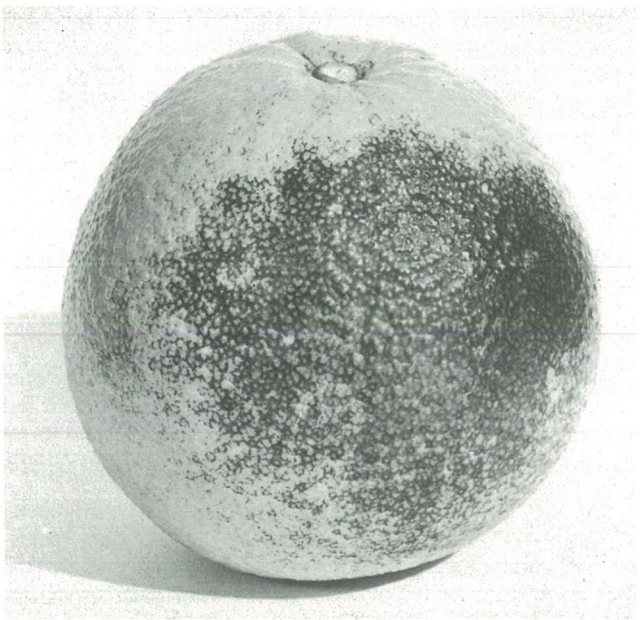


Photomicrograph of rust mite blemishes on orange. The mites' elongate white cast skins are present. It is characteristic that the blemish markings have poorly-defined edges.

Citrus rust mite mainly infests and blemishes the sheltered side of the fruit.



Citrus rust thrips blemishes. Shown here for comparison with rust mite injury.



Brown citrus rust mite infests and blemishes the exposed side of the fruit.

Tegolophus australis occurs commonly in small numbers on foliage of coastal citrus trees, often causing purple-brown stippled marking on the upper sides of mature leaves. This is not important and does not necessarily indicate that fruit infestation will develop. Sometimes *T. australis* infestation of green bark on young trees causes die-back of twigs.

Dispersal Mites can readily be found on trees in nurseries and are probably introduced to young stock on buds. They are probably moved from tree to tree by visiting birds and insects, man, and wind. This type of spread is likely to be aided by the habit, recorded for *Phyllocoptruta oleivora*, of rearing up on the false feet at the end of the abdomen.

Control measures

NATURAL The use of DDT in experimental spraying of citrus in coastal districts usually increased rust mite blemishing, which suggested that there are important predators.

Three predatory phytoseiid mites and many ladybirds, especially *Serangium bicolor* Blackburn, *Stethorus nigripes* Kapur, and steel blue ladybird, *Halmus chalybeus*, have been recorded in an association with *Phyllocoptruta oleivora*, *Tegolophus australis* and citrus red mite on orange trees near Gosford (Beattie, 1978).

APPLIED Zineb is usually effective for fruit protection against both rust mites in New South Wales, if used as a single application of 0.07 per cent zineb in 0.5 per cent petroleum oil in December or January. In other countries *P. oleivora* is no longer controlled adequately by zineb, but maneb and mancozeb are effective (Bailey and Dean, 1962; Swirski *et al*, 1967). Mancozeb is commonly used here on coastal Valencias in summer against black spot disease, and this probably controls rust mite also.

Ethion 0.075 per cent-in-petroleum oil 1.25 per cent is also an effective spray in summer.

Sulphur compounds kill rust mite, but they are also damaging to citrus trees in hot weather, so their usefulness is limited. Following a season of serious infestation by *P. oleivora*, spraying in winter or spring with dispersible sulphur 0.3 per cent may be needed, followed by the zineb spray in summer. The sulphur can be applied in mixture with Bordeaux fungicide at petal-fall, if desired.

Petroleum oil 2 per cent spray kills *Tegolophus australis* but has no long-lasting effect.

Broad mite *Polyphagotarsonemus latus*

Importance and Distribution Broad mite has been known for many years as a pest in glasshouses and of summer-growing ornamentals and vegetables. It was recognized as the cause of blemishing on citrus fruits at Gosford in 1960 and in Morocco at about the same time (Delucchi, 1965). In New South Wales, the problem is confined to coastal districts and is most frequent on summer-crop lemon fruits. These set in summer-autumn, when broad mite may develop and blemish the young fruits rapidly. The crop is usually valuable, so down-grading causes considerable loss of profit.

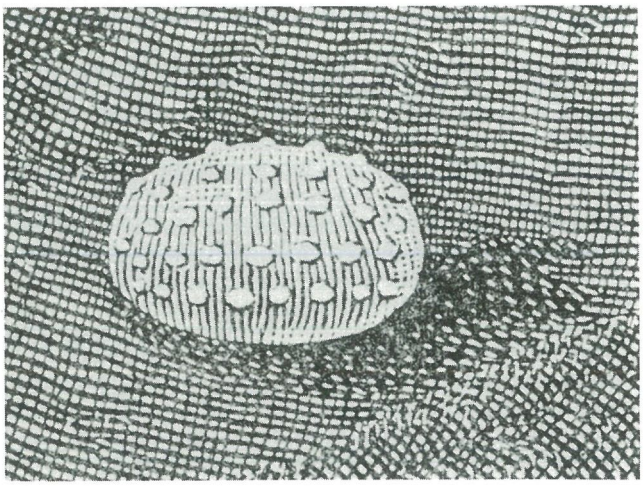
Conditions for Infestation Warm humid summer-autumn weather and the availability of tender growth suit this mite. In orchards it infests weeds, particularly potato weed, *Galinsoga parviflora*, and moves to citrus if there are young fruits or young foliage. Intermediate-crop citrus fruits, such as summer-crop lemons, are likely to be susceptible at this time, but most main-crop fruits are beyond the susceptible stage.

Plants attacked Broad mite attacks the young growth of a very wide range of dicotyledonous crop, ornamental and weed plants.

Description and Life History The adults are shining and translucent-white or very pale yellow, with oval bodies. Females are 0.25 millimetre long, but males are smaller. The mites have four pairs of legs, and the males are very active. The eggs are 0.1 millimetre long, convex on the upper surface and ornamented with tubercles, and are laid flat on and adhering firmly to the infested tissue.

Hussey *et al* (1969) recorded that under glasshouse conditions females produce about five eggs daily, in an average life of ten days, and these hatch in two or three days and the young mites become adult within a further four days.

Before mating, pre-adult females are carried about by males, which wander very actively. This takes infestation to new sites and depopulates old sites, as unfertilized females produce only male young (Gadd, 1946).

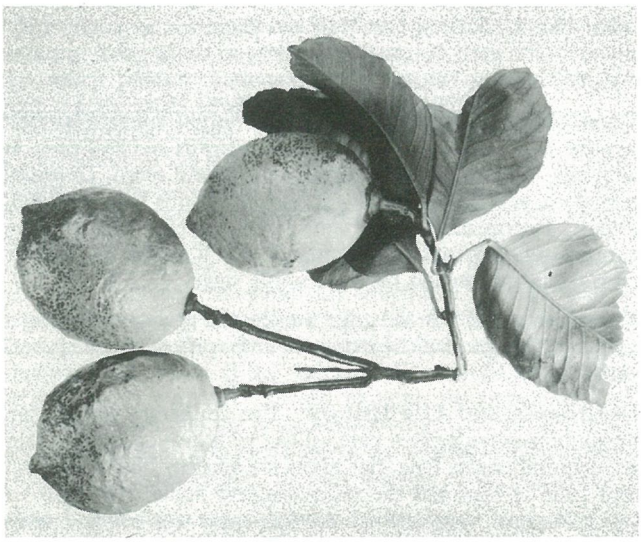


Broad mite egg. (Length 0.1 mm)

Injury Fruit injury on lemons begins as a diffuse brown marking on young fruits 1 to 4 centimetres long, usually on the undersurfaces. As the mites feed, the marking extends over much or all of the fruit surface as a silver or lead-coloured blemish with 'sharkskin' texture and sometimes with bronze-coloured margins. Fruits up to 2.5 centimetres long may become completely silvered in two weeks. Young lemons more than 4 centimetres long are not infested.

Blemishing of main crop Valencias has been seen as diffuse brown markings on slow-growing young fruits, such as fruits inside the tree or on the south side.

Infested young foliage becomes inrolled, curved and bronzed, but this injury is important only on nursery trees.



Lemons blemished by broad mite.

Dispersal Broad mites are believed to be distributed by wind, visiting insects, birds and man.

Control measures

NATURAL Little is known of the natural enemies. A ladybird, *Scymnus* sp., has been seen feeding on the mites.

APPLIED Spraying should be done when infestation is first detected, if there are enough young undamaged fruits to warrant protection. Suitable sprays in summer–autumn are ethion 0.06 per cent-in-petroleum oil 1 per cent, or dicofol 0.04 per cent emulsion. At the same time, infested weeds should be sprayed or destroyed. Spraying does not give long-term protection and re-infestation can develop rapidly.

Citrus red mite *Panonychus citri*

Importance and Distribution Citrus red mite feeds on foliage, green bark and fruit, and can cause severe leaf-fall and twig die-back and fruit-blemishing. Ebeling (1950) considered it to be second only to red scale in importance in California. It is a pest in most other citrus-producing countries. In Australia it was first recorded at Oxford Falls, Sydney, in 1966 (Gibson, 1968) and later at Gosford. To date, this mite has not been known outside the Gosford district and Sydney Metropolitan Area.

Conditions for Infestation It appears that infestation is favoured by dry conditions at the mild temperatures of spring and autumn. Experience in California shows that the mite can thrive in both coastal and dry inland districts.

Plants attacked In other countries a number of broad-leafed trees and shrubs are known to be hosts (Gibson, 1968), but so far in New South Wales only citrus has been infested.

Description and Life History Adult females are about 0.5 millimetre long, oval-bodied and plump with four pairs of legs. They are fairly similar in size and shape to the bean spider mite – a common pest of beans and cucumbers – but are dark red to purple-red, and have long bristles on prominent tubercles on the back and sides. Males are smaller and narrowed posteriorly. The adults move about readily.

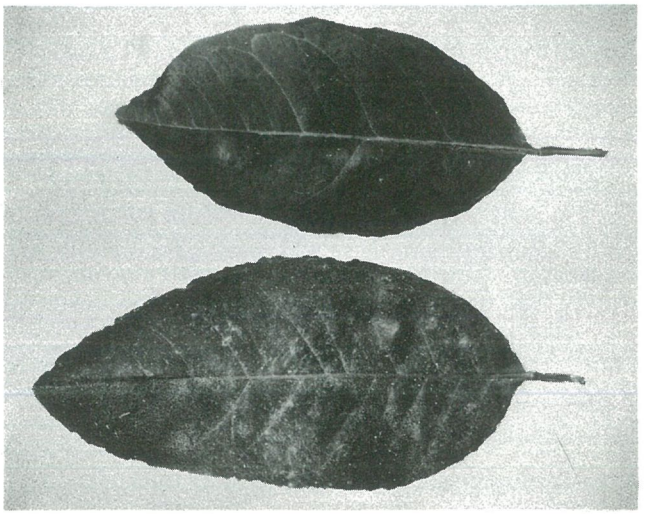
The eggs are laid on the infested surface, and usually along the midribs of the leaves. The eggs are bright red, nearly spherical, and approximately 0.13 millimetre in diameter. A vertical stalk arises from the top of each egg and ten or twelve very fine guy threads radiate from its tip to the plant surface.

Females lay 20 to 30 eggs, at the rate of two or three per day, and these hatch in 8 to 30 days. There are a larval and two nymphal stages, each lasting several days, before the adult stage is reached. In summer, a generation from egg to egg may span as little as three weeks and adults may live for 18 days (Ebeling, 1950). Development continues all through the year, but at a slower rate in cooler conditions.

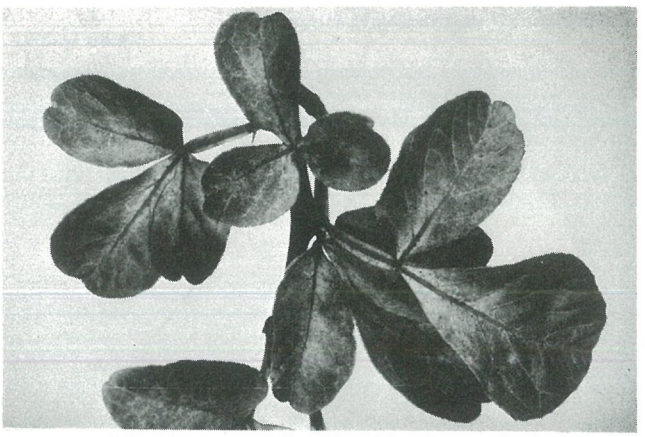
Injury The mites feed on leaves, preferring the light green maturing foliage, and on green bark and fruits, both immature and mature. The scratch-like feeding marks give the leaves a pale appearance and blemish fruit. In very light infestations, the feeding marks are most commonly seen at the bases of the leaves.

Heavy infestation leads to defoliation and twig die-back, especially if trees are under stress from drying conditions such

as wind (Ebeling, 1950). Defoliation occurs mostly in the tops of trees, and the leaf lesion 'mesophyll collapse' may be associated.



Orange leaf damaged by citrus red mite below, undamaged leaf above.



Poncirus trifoliata leaves severely affected by citrus red mite.

Dispersal Citrus red mite is spread by man moving infested plants and fruits, and orchard equipment which has been in contact with infested trees. It is spread also by wind and by visiting birds and insects.

Control measures

NATURAL In a study in the Gosford district of natural enemies of citrus red mite, Beattie (1978) has recorded three predatory phytoseiid mites and many ladybirds, especially *Serangium bicolor, Stethorus nigripes* and steel blue ladybird, *Halmus chalybeus*, in an association with citrus red mite and brown citrus rust mite.

In the United States of America fungal disease (Muma, 1969) and predatory mites and virus disease (McMurtry, 1969) are known to reduce mite numbers. Disease has been reported in citrus red mite at Sydney (Snowball, 1970).

APPLIED Trees should be watched for infestation, and sprayed promptly if mite numbers are increasing markedly in mild dry weather. A thorough application of dicofol 0.05 per cent kills the active stages of the mites. If many eggs are present, a second spraying may be required after they hatch.

A flat mite *Brevipalpus* sp.

These mites occur on citrus trees in coastal and inland areas, but their status as pests in New South Wales is not clear. They are often seen on maturing blemished citrus fruits, and they have been blamed for the silver blemishing on lemons caused by broad mite.

The adult mites are red and flat, and about 0.25 millimetre long, with two pairs of short legs at the front of the body and two pairs of short legs flanking the narrow abdomen. The eggs are red and oval, and usually laid singly. These mites are seldom seen moving about.

In California, the citrus flat mite, *Brevipalpus lewisi*, blemishes orange fruits, tending to infest areas of the fruit surface already damaged by insects (Elmer and Jeppson, 1956). In Florida, brevipalpid mites have been associated with a disease known as 'leprosis', 'Florida scaly bark' and 'nailhead rust' which causes lesions on fruits, leaves and bark (Pratt, 1958). In South America, the disease 'lepra explosiva' is associated with brevipalpid mites (Vergani, 1956); according to Knorr (1950), this disease seems to be the same as Florida scaly bark.

ARANEIDA

Webbing spider *Ixeuticus longinquus*

In inland areas foliage of citrus trees may be webbed together by these small grey-brown gregarious spiders. The webbing interferes with the normal development of foliage and fruit, and protects black scale and mealybugs. The spiders are very numerous in the webs and may be a nuisance to people harvesting the fruit. The problem was described by Cock (1931), who attributed the cause to another spider, *Lampona obscoena* Koch.

The spiders can be destroyed by spraying with maldison 0.1 per cent plus 1 per cent white oil. It may be necessary to break up thick webs mechanically to allow better penetration of the spray.

Nests of webbing spider on citrus trees.

MOLLUSCA
GASTROPODA SIGMURETHRA

Common garden snail *Helix aspersa*

Importance and Distribution This snail can be most destructive, by causing foliage and fruit injury. It has been known as a pest in coastal districts for many years, especially in low-lying orchards near watercourses, but it is also prevalent in inland irrigated areas. It shelters in leaf litter under citrus trees.

Conditions for Infestation Continuous showery weather in summer or autumn favours snail numbers and activity. Reproduction takes place, feeding is stimulated, and tender plant growth is available for the young snails. Activity declines in cold weather and there is only sparse feeding during winter. The snails may become active again in wet conditions in spring.

In dry conditions, snails are inactive and seal over the opening of the shell, or seal themselves to some object.

Plants attacked Snails have many hosts among broad-leafed weeds in citrus orchards and these help the pest to survive in dry weather. When conditions become favourable, and the citrus trees offer attractive feeding, the snails move on to the lower foliage. They show no obvious preference among varieties, but navels are most commonly subject to important damage. This may be because navels are usually grown on the lowest sections of coastal orchards where snails are most likely to be prevalent. Also the maturing fruit is tender when snails are active in autumn, and navels are sprayed less than Valencias or lemons with Bordeaux or other copper fungicides, which are strongly repellent to snails.

Description and Life History The snail is hermaphroditic. All adults can lay eggs, and mating occurs on the ground beneath the trees in showery weather in January and February. The eggs are white, round and about 3 millimetres in diameter. They are laid about 3 centimetres below the soil surface in clusters of about 40; each snail can lay 200 to 400 eggs. The young are fragile and light brown, and resemble the adults except that the shell has only one whorl. Development to maturity takes one to two years and the adults are long-lived. The shell of the adult has four-and-a-half to five whorls and a diameter of about 2.5 centimetres. The snail has a fleshy mouth, but inside is a jaw of chitin – hard, sharp and toothed.

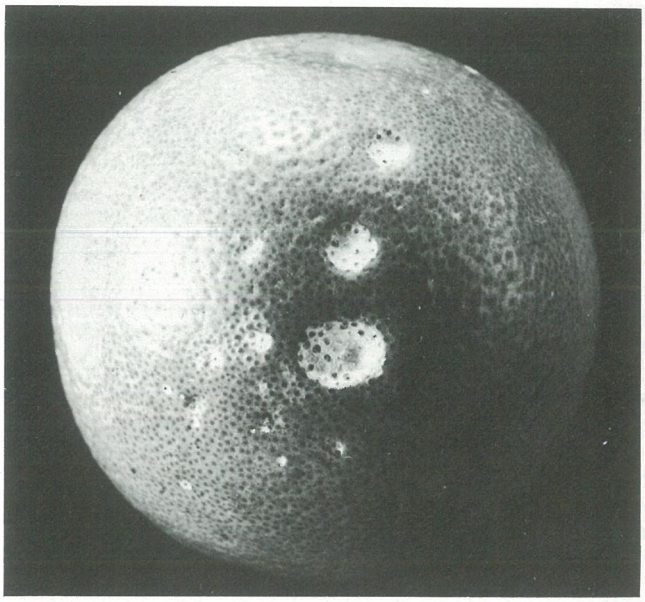
Injury Young snails feed on the surfaces of young leaves, often only penetrating shallowly, leaving a window-pane effect. They graze on the surface of green citrus fruits, giving them a mottled grey appearance. Older snails eat holes in the leaves and may reduce them to veins only. They may eat into both green and ripening fruits, gouging out circular holes. Green bark is not attacked, but the dry bark of dead twigs is eaten, leaving the wood stark white.

Dispersal Snails can move considerable distances over soil from infestation sources to trees in orchards. However, most move in to new areas as passengers on transported containers. Snails seal themselves up in field boxes and bins used for picking, and thus find their way to new groves.

Control measures

NATURAL Birds and rats undoubtedly kill many snails.

Common garden snail damaging citrus leaf.



Snail injury to orange.

APPLIED Poison bait has been used for many years to control snails in citrus orchards. Before the snails move up into the trees, bait should be scattered under the trees or alongside places from which the snails are expected to enter the grove. This should be done in the late afternoon.

Metaldehyde and bran bait is prepared from 1 kilogram finely-powdered metaldehyde mixed with 50 kilograms bran and sufficient water to make the bait crumbly and moist. If preferred, it can be used dry. It is also available as a prepared bait in pellets. The metaldehyde bait is effective for only short periods. A proprietary methiocarb pellet bait will kill snails over a much longer period.

Poultry and other animals should be kept away from snail baits.

Spraying with azinphos-methyl 0.05 per cent emulsion is used for snail control in California, but has seldom been used in Australia.

Bordeaux spray has proved to be most satisfactory for preventing snail infestation in citrus in New South Wales. It is used at 250 grams bluestone–250 grams lime–100 litres water strength, plus 1 per cent white oil. It kills some young snails if they are active at the time of application. All feeding stops, and the spray residue acts as a repellent and protects the trees for several months.

Ducks can also be used most effectively for snail control. They may be restricted in range by temporary netting fences which are gradually moved over the whole area. Recommendations for the successful use of ducks in snail control are listed below.

- ☐ Use only active breeds, such as Khaki Campbell or Indian Runner ducks.
- ☐ Five to eight ducks per hectare are enough when used as a permanent method of control. More may be needed to reduce a very heavy infestation.
- ☐ House the ducks in or near the orchard and lock them up at night.
- ☐ Feed them only in the evening at their quarters.
- ☐ Do not allow them access to areas of water in which they could swim.
- ☐ Have only one drake per flock of about twelve ducks.
- ☐ Do not use poison baits where ducks are likely to be run, but Bordeaux mixture spray may be used safely.

References

Allen, W. J. (1901). Experiments on the destruction of scale insects. *Agricultural Gazette of New South Wales* **12**: 1092–1104.

Allen, W. J., Blunno, M., Froggatt, W. W. and Guthrie, F. B. (1898). Insect and fungus diseases of fruit-trees and their remedies. *Agricultural Gazette of New South Wales* **9**: 1216–21.

Allman, S. L. (1939). The Queensland fruit fly – observations on breeding and development. *Agricultural Gazette of New South Wales* **50**: 499–501, 547–9.

Annecke, D. P. (1959). The effect of parathion and ants on *Coccus hesperidum* L. (Coccidae: Hemiptera) and its natural enemies. *Journal of the Entomological Society of Southern Africa* **22**: 245–74.

Annecke, D. P. (1966). Biological studies on the immature stages of soft brown scale, *Coccus hesperidum* Linnaeus (Homoptera: Coccidae). *South African Journal of Agricultural Science* **9**: 205–28.

Annecke, D. P. (1969). Recent developments in biological and integrated control of citrus pests in South Africa. *Proceedings First International Citrus Symposium, Riverside, California* **2**: 849–54.

Anon (1951). *Fumigation for Control of Scale Insects of Citrus Trees.* New South Wales Department of Agriculture, Entomological Branch, Division of Science Services, Sydney. 10pp.

Anon (1951). *The Queensland Agricultural and Pastoral Handbook. Insect Pests and Diseases of Plants. Vol. III.* Government Printer, Brisbane. 560pp.

Anon (1966). Citrus gall wasp. *Annual Report Entomology Branch Department of Agriculture, New South Wales*, p. 22, Sydney. 42pp.

Anon (1974). *New South Wales Department of Agriculture Annual Report 1972–73.* Government Printer, Sydney. 208pp.

Anon (1980). *1980–1982 Treatment Guide for California Citrus Crops.* University of California, Division of Agricultural Sciences Leaflet 2903. 97pp.

Arthur, J. M. and Harrison, T. H. (1926). Calcium cyanide dust for fumigation of citrus trees. *Agricultural Gazette of New South Wales* **37**: 245–8.

Bailey, J. C. and Dean, H. A. (1962). Zineb versus maneb for citrus rust mite control. *Journal of the Rio Grande Valley Horticultural Society* **16**: 22–5.

Beattie, G. A. C. (1978). Biological control of citrus mites in New South Wales. *Proceedings of the International Society of Citriculture*, 1978: 156–8.

Bedford, E. C. G. (1968). The biological control of red scale, *Aonidiella aurantii* (Mask.), on citrus in South Africa. *Journal of the Entomological Society of Southern Africa* **31**: 1–15.

Benton, R. J. (1927). Fumigation of citrus trees. *Agricultural Gazette of New South Wales* **38**: 77–80.

Bess, H. A. (1958). The green scale, *Coccus viridis* (Green) (Homoptera: Coccidae), and ants. *Proceedings of the Hawaiian Entomological Society* **16**: 349–55.

Blumberg, D. (1935). The life cycle and seasonal history of *Ceroplastes rubens. Proceedings of the Royal Society of Queensland* **46**: 18–32.

Bodenheimer, F. S. (1951). *Citrus Entomology in the Middle East.* Dr W. Junk, The Hague, 663pp.

Boyce, A. M. and Korsmeier, R. B. (1941). The citrus bud mite, *Eriophyes sheldoni* Ewing. *Journal of Economic Entomology* **34**: 745–56.

Boyce, A. M. and Maxwell, K. E. (1938). The new citrus bud mite. *California Citrograph* **23**: 109, 152.

Brimblecombe, A. R. (1956). Studies of the Coccoidea 5. The genus *Ceroplastes* in Queensland. *Queensland Journal of Agricultural Science* **13**: 107–22.

Brooks, R. F. and Thompson, W. L. (1963). Investigations of new scalicides for Florida citrus. *The Florida Entomologist* **46**: 279–84.

Browning, T. O. (1959). The long-tailed mealybug, *Pseudococcus adonidum* (L.), in South Australia. *Australian Journal of Agricultural Research* **10**: 322–39.

Carman, G. E. (1978). Chemical control of citrus pests. *Proceedings of the International Society of Citriculture* 1978: 158–62.

Carver, Mary (1978). The black citrus aphids, *Toxoptera citricidus* (Kirkaldy) and *T. aurantii* (Boyer de Fonscolombe) (Homoptera: Aphididae). *Journal of the Australian Entomological Society* **17**: 263–70.

Cock, S. A. (1931). The webbing spider of citrus trees. *Journal of Agriculture, Victoria* **29**: 82–5.

Cohen, I. (1969). Biological control of citrus pests in Israel. *Proceedings First International Citrus Symposium, Riverside, California* **2**: 769–72.

Compere, H. (1961). The red scale and its insect enemies. *Hilgardia* **31**: 173–278.

Coquillet, D. W. (1890). The use of hydrocyanic acid gas for the destruction of the red scale. *Insect Life* **21**: 201–07.

DeBach, P. (1959). New species and strains of *Aphytis* (Hymenoptera: Eulophidae) parasitic on the California red scale, *Aonidiella aurantii* (Mask.) in the Orient. *Annals of the Entomological Society of America* **52**: 354–62.

DeBach, P. (1969). Biological control of diaspine scale insects on citrus in California. *Proceedings First International Citrus Symposium, Riverside, California* **2**: 801–15.

Dekle, G. W. (1965). *Arthropods of Florida and Neighbouring Land Areas. Vol. 3. Florida Armored Scale Insects.* Florida Department of Agriculture, Division of Plant Industry, Gainesville, Florida. 265pp.

De Lotto, G. (1965). On some Coccidae (Homoptera) chiefly from Africa. *Bulletin of the British Museum (Natural History) (Entomology)* **16**: 175–239.

Delucchi, V. L. (1965). *Hemitarsonemus latus* Banks (Acarina, Tarsonemidae). A mite injurious to citrus in Morocco. *Al Awamia* **6**: 17–29. (Reviewed in *Review of Applied Entomology*, Series A, **53**: 114–5).

Ebeling, W. (1936). Effects of oil spray on California red scale at various stages of development. *Hilgardia* **10**: 95–125.

Ebeling, W. (1950). *Subtropical Entomology.* Lithotype Process Co., San Francisco. 747pp.

Ebeling, W. (1959). *Subtropical Fruit Pests.* University of California, Division of Agricultural Sciences. 436pp.

Elmer, H. S. and Jeppson, L. R. (1956). Biology, control of citrus flat mite. *California Citrograph* **41**: 311-2.

Elmer, H. S. (1960). Evaluation of insecticides for control of the Fuller rose beetle on citrus in California. *Journal of Economic Entomology* **53**: 164-5.

Flaherty, D. L., Pehrson, J. E. and Kennett, C. E. (1973). Citrus pest management studies in Tulare County. *California Agriculture*, November 1973, 3-7.

Frazer, L. (1937). The distribution of sooty mould fungi and its relation to certain aspects of their physiology. *Proceedings of the Linnaean Society of New South Wales* **62**: 35-56.

French, C. (1891). *Handbook of the Destructive Insects of Victoria*. I. Government Printer, Melbourne. 153pp.

Friend, A. H. (1945). The fruit-tree root weevil (*Baryopadus squalidus.*). *Agricultural Gazette of New South Wales* **56**: 552.

Friend, A. H. (1957). Artificial infestation of oranges with Queensland fruit fly. *Journal of the Australian Institute of Agricultural Science* **23**: 77-80.

Froggatt, W. W. (1897). The fruit-maggot fly (*Tephritis tryoni*, n. sp). *Agricultural Gazette of New South Wales* **8**: 410-14.

Froggatt, W. W. (1898). Fruit-tree and vine pests. *Agricultural Gazette of New South Wales* **9**: 41-7.

Froggatt, W. W. (1899a). Entomological notes for 1898. *Agricultural Gazette of New South Wales* **10**: 873-9.

Froggatt, W. W. (1899b). Notes on fruit-maggot flies, with descriptions of new species. *Agricultural Gazette of New South Wales* **10**: 497-504.

Froggatt, W. W. (1923). *Forest Insects of Australia*. New South Wales Government Printer, Sydney. 171pp.

Gadd, C. H. (1946). Observations on the yellow tea-mite *Hemitarsonemus latus* (Banks) Ewing. *Bulletin of Entomological Research* **37**: 157-62.

Gallard, L. (1920). Notes on the dicky rice weevil (*Prosayleus phytolymus* Olliff). *Agricultural Gazette of New South Wales* **31**: 280-84.

Gellatley, J. G. (1967). Citrus blossom bug. *Agricultural Gazette of New South Wales* **78**: 377.

Georgala, M. B. (1963). Prospect of a new approach to red scale control. *South African Citrus Journal* No. 352, 5-7.

Gibson, F. A. (1968). Citrus red mite, *Panonychus citri* (McGregor) (Tetranychidae: Acari) recorded from New South Wales. *Australian Journal of Science* **30**: 273.

Gibson, F. A. and Gellatley, J. G. (1968). *Epimegastigmus brevivalvus* Gir. (Hymenoptera: Torymidae), a parasite of citrus gall wasp in the Sydney district. *Agricultural Gazette of New South Wales* **79**: 312-4.

Gurney, W. B. (1910, 1911, 1912). Fruit flies and other insects attacking cultivated and wild fruits in New South Wales. *Agricultural Gazette of New South Wales* **21**: 423-33, **22**: 722-7, **23**: 75-80.

Gurney, W. B. (1934). Records of some new insect pests. *Agricultural Gazette of New South Wales* **45**: 452-4.

Gurney, W. B. (1936). Parasites of white wax scales collected in East Africa. *Agricultural Gazette of New South Wales* **47**: 453-6, 464, 472.

Hackman, R. H. (1951). The chemical composition of the wax of the white wax scale, *Ceroplastes destructor* (Newstead). *Archives of Biochemistry and Biophysics* **33**: 150-54.

Hackman, R. H. and Trichojus, V. M. (1952). The composition of the honeydew excreted by Australian coccids of the genus *Ceroplastes*. *Biochemical Journal* **51**: 653-6.

Hely, P. C. (1933). Citrus red scale. Experiments with liquefied hydrocyanic acid gas fumigation. *Agricultural Gazette of New South Wales* **44**: 823-6.

Hely, P. C. (1937). A citrus weevil (*Asynonychus godmani*). *Agricultural Gazette of New South Wales* **48**: 344.

Hely, P. C. (1939). The citrus bud mite (*Eriophyes* sp). *Agricultural Gazette of New South Wales* **50**: 495-7.

Hely, P. C. (1940). The citrus red scale problem in New South Wales with special reference to fumigation. *Journal of the Australian Institute of Agricultural Science* **6**: 140-46.

Hely, P. C. (1944). The white louse scale (*Protaspis citri*). A pest of coastal citrus trees. *Agricultural Gazette of New South Wales* **55**: 283-5.

Hely, P. C. (1944). The bronze orange bug (*Rhoecocoris sulciventris* Stål). A citrus pest of the North Coast. *Agricultural Gazette of New South Wales* **55**: 397-401, 406.

Hely, P. C. (1948). Fuller's rose weevil (*Pantomorus (Asynonychus) godmani* Crotch). A troublesome pest of citrus trees. *Agricultural Gazette of New South Wales* **59**: 144-8.

Hely, P. C. (1960). Dispersal of white wax scale (*Ceroplastes destructor* Newst.) by wind. *Journal of the Australian Institute of Agricultural Science* **26**: 355-6.

Hely, P. C. (1964). Two insect pests of citrus. *World Crops* **16**: 53-7.

Hely, P. C. (1968). *The Entomology of Citrus in New South Wales*. Miscellaneous Publication No. 1, Australian Entomological Society, Brisbane. 20pp.

Hely, P. C. and Duncan, J. H. (1959). Soft brown scale *Coccus hesperidum* L. An experiment in control on citrus trees. *Agricultural Gazette of New South Wales* **70**: 537-40.

Hely, P. C. and Gellatley, J. G. (1960). Control of red scale on citrus trees. *Agricultural Gazette of New South Wales* **71**: 580-84.

Hely, P. C. and Gellatley, J. G. (1961). The purple or mussel scale *Lepidosaphes beckii* (Newm.). *Agricultural Gazette of New South Wales* **72**: 14-8, 39.

Hely, P. C. and Gellatley, J. G. (1962). Experiments on red scale control in coastal New South Wales. *Agricultural Gazette of New South Wales* **73**: 70-2, 100-02.

Hely, P. C. and Levitt, E. C. (1950). White wax scale control on citrus. Demonstration plots on Central Coast orchards. *Agricultural Gazette of New South Wales* **61**: 307-10.

Hely, P. C. and Wason, E. J. (1945). Control of red scale on citrus. Experiments on the Murrumbidgee Irrigation Area. *Agricultural Gazette of New South Wales* **56**: 262-7.

Hughes, R. D., Carver, Mary, Casimir, M., O'Loughlin, G. T. and Martyn, E. J. (1965). A comparison of the numbers and distribution of aphid species flying over eastern Australia in two successive years. *Australian Journal of Zoology* **13**: 823-39.

Hussey, N. W., Read, W. H. and Hesling, J. J. (1969). *The Pests of Protected Cultivation. The Biology and Control of Glasshouse and Mushroom Pests*. Edward Arnold (Publishers) Ltd, London. 404pp.

Jenkins, C. F. H. and Shedley, D. G. (1953). The citrus white fly (*Aleuroplatus citri* Tak.). *Journal of Agriculture of Western Australia* (3rd Series) **2**: 49-55.

Jenkins, C. F. H. and Shedley, D. G. (1956). The Mediterranean fruit fly. *Journal of Agriculture of Western Australia* (3rd Series) **5**: 341-51.

Jeppson, L. R. and di Pietri-Tonelli, P. (1963). Evidence that citrus bud mite is an old lemon pest. *Citrus Leaves*, May, p12.

Jeppson, L. R. (1969). Impact of insect and mite resistance on chemical control programs on citrus. *Proceedings First International Citrus Symposium, Riverside, California* **2**: 917-21.

Jones, E. L. and Skepper, A. H. (1965). Suppression of Queensland fruit fly, *Dacus (Strumeta) tryoni* (Frogg.) Trypetidae (Dipt.) in Narrandera, New South Wales. *Agricultural Gazette of New South Wales* **76**: 501-03.

Keifer, H. H. (1964). *Eriophyid studies B-12*. Bureau of Entomology, California Department of Agriculture, p2.

Kiely, T. B. (1963). Black spot of Valencia oranges. Experiments in control on the Central Coast of N.S.W. *Agricultural Gazette of New South Wales* **74**: 652-9.

Knorr, L. C. (1950). Etiological association of a *Brevipalpus* mite with Florida scaly bark of citrus. *Phytopathology* **40**: 15.

Leggo, D., Gellatley, J. G., Seberry, J. A., Peggie, I. D., Long, J. K. and Hall, E. G. (1965). Post-harvest sterilization of oranges against Queensland fruit fly. *Agricultural Gazette of New South Wales* **76**: 274-8.

McKenzie, H. L. (1937). Morphological differences distinguishing California red scale, yellow scale and related species. *University of California Publications in Entomology* **6**: 323-6.

McKenzie, H. L. (1956). *The Armored Scale Insects of California*. University of California Press, Berkeley and Los Angeles. 209pp.

McKenzie, H. L. (1967). *Mealybugs of California*. University of California Press, Berkeley and Los Angeles. 526pp.

McLaren, I. W. (1971). A comparison of the population growth potential in California red scale, *Aonidiella aurantii* (Maskell), and yellow scale,

A. citrina (Coquillet), on citrus. *Australian Journal of Zoology* **19**: 189–204.

McLaren, I. W. and Buchanan, G. A. (1973). Parasitism by *Aphytis chrysomphali* Mercet and *A. melinus* DeBach of California red scale *Aonidiella aurantii* (Maskell) in relation to seasonal availability of suitable stages of the scale. *Australian Journal of Zoology* **21**: 111–7.

McMurtry, J. A (1969). Biological control of citrus red mite in California. *Proceedings First International Citrus Symposium, Riverside, California* **2**: 855–62.

Martin, B. H. and Black, R. F. (1960). Heat treatment of citrus for control of red scale. I. Trials of Washington navel fruit in a dehydrator. *Australian Journal of Agricultural Research* **2**: 197–207.

May, A. W. S. (1963). An investigation of fruit flies (Fam. Trypetidae) in Queensland. 1. Introduction, species, pest status and distribution. *Queensland Journal of Agricultural Science* **20**: 1–82.

Melander, A. L. (1914). Can insects become resistant to sprays? *Journal of Economic Entomology* **7**: 167–73.

Morse, F. W. (1897). *The Use of Gases against Scale Insects*. California Agricultural Experiment Station Bulletin 71.

Mosse-Robinson, I. (1968). Fruit-sucking moths (Lepidoptera: Noctuidae). *Australian Zoologist* **14**: 290–93.

Mosse-Robinson, I. and Hely, P. C. (1957). The green gum tree hopper (*Torbia perficita* Walk.). *Agricultural Gazette of New South Wales* **68**: 542–4.

Musgrove, C. H. and Carman, G. E. (1965). Argentine ant control on citrus in California with granular formulations of certain chlorinated hydrocarbons. *Journal of Economic Entomology* **58**: 428–34.

Muma, M. H. (1969). Biological control of various insects and mites on Florida citrus. *Proceedings First International Citrus Symposium, Riverside, California* **2**: 863–70.

Noble, N. S. (1936a). *The Citrus Gall Wasp* (*Eurytoma fellis Girault*). New South Wales Department of Agriculture Science Bulletin No. 53, 41pp.

Noble, N. S. (1936b). *Pristhesancus papuensis* Stål., an 'assassin bug'. *Journal of Australian Institute of Agricultural Science* **2**: 124–6.

Noble, N. S. (1938). *Epimegastigmus (Megastigmus) brevivalvus Girault: a Parasite of the Citrus Gall Wasp* (*Eurytoma fellis Girault*); with notes on several other species of hymenopterous gall inhabitants. New South Wales Department of Agriculture Science Bulletin No. 65 46pp.

Olliff, A. S. (1890). Insect Pests. The elephant beetle (*Orthorrhinus cylindrirostris*, Fabr.), *Agricultural Gazette of New South Wales* **1**: 278–81.

Olliff, A. S. (1891). Entomological Notes. *Agricultural Gazette of New South Wales* **2**: 71–8.

Olliff, A. S. (1892). Entomological Notes. Bronzy orange bug (*Oncoscelis sulciventris*, Stal). *Agricultural Gazette of New South Wales* **3**: 368–70.

Olliff, A. S. (1892). A new longicorn beetle (*Uracanthus cryptophagus*) attacking orange trees. *Agricultural Gazette of New South Wales* **3**: 895–7.

Pratt, R. M. (1958). *Florida Guide to Citrus Insects, Diseases and Nutritional Disorders in Colour*. Agricultural Experiment Station, Gainesville. 191pp.

Quayle, H. J. (1916). Dispersion of scale insects by the wind. *Journal of Economic Entomology* **9**: 486–93.

Quayle, H. J. (1916). Are scales becoming resistant to fumigation? *California University Journal of Agriculture* **3**: 333–4, 358.

Quayle, H. J. (1928). Fumigation with calcium cyanide dust. *Hilgardia* **3**: 207–32.

Quayle, H. J. (1938). *Insects of Citrus and Other Subtropical Fruits*. Comstock Publishing Co., Ithaca, N.Y. 583pp.

Quednau, F. W. (1964). A contribution on the genus *Aphytis* Howard in South Africa. (Hymenoptera: Aphelinidae). *Journal of the Entomological Society of Southern Africa* **27**: 86–116.

Riehl, L. A. (1969). Advances relevant to narrow-range spray oils for citrus pest control. *Proceedings First International Citrus Symposium, Riverside, California* **2**: 897–907.

Riehl, L. A. and Carman, G. E. (1953). Narrow cut petroleum fractions of naphthenic and paraffinic composition for control of California red scale. *Journal of Economic Entomology* **46**: 1007–13.

Rosen, D. (1967). Biological and integrated control of citrus pests in Israel. *Journal of Economic Entomology* **60**: 1422–7.

Shaw, J. G. and Moreno, D. S. (1971). New red scale detector. *California Citrograph* **56**: 149–50.

Siegler, E. H. and Popenoe, C. H. (1925). The fatty acids as contact insecticides. *Journal of Economic Entomology* **18**: 292–9.

Smith, D. (1976). The seasonal history and control of *Ceroplastes rubens* Maskell on citrus in south-east Queensland. *Queensland Journal of Agricultural and Animal Sciences* **33**: 23–30.

Smith, H. S. (1942). A race of *Comperiella bifasciata* successfully parasitizes California red scale. *Journal of Economic Entomology* **35**: 809–12.

Smith, R. H. (1932). Experiments with toxic substances in highly refined spray oils. *Journal of Economic Entomology* **25**: 988–90.

Snowball, G. J. (1966). Status of introduced parasites of Queensland fruit fly (*Strumeta tryoni* (Froggatt)), 1962–65. *Australian Journal of Agricultural Research* **17**: 719–39.

Snowball, G. J. (1968). Prospects for biological control of white wax scale (*Gascardia destructor*) in Australia by South African natural enemies. *Journal of the Entomological Society of Australia (N.S.W.)* **5**: 23–33.

Snowball, G. J. (1970). *Ceroplastes sinensis* Del Guercio (Homoptera: Coccidae), a wax scale new to Australia. *Journal of the Australian Entomological Society* **9**: 57–66.

Snowball, G. J. (1970). A disease of citrus red mite *Panonychus citri* (McGregor) (Acarina: Tetranychidae). *Journal of the Australian Entomological Society* **9**: 74–5.

Stroyan, H. L. G. (1961). Identification of aphids living on citrus. *FAO Plant Protection Bulletin* **9**: 45–65.

Summerville, W. A. T. (1931). The larger horned citrus bug (*Biprorulus bibax* Breddin). *Queensland Agricultural Journal* **36**: 543–88.

Summerville, W. A. T. (1934). Queensland citrus scale insects and their control. *Queensland Agricultural Journal* **41**: 450–86, 568–91; **42**: 4–33, 186–206.

Summerville, W. A. T. (1935). The bronze orange bug. *Queensland Agricultural Journal* **43**: 245–53.

Swirski, E. and Amitai, S. (1959). Contribution to the biology of the citrus rust mite (*Phyllocoptruta oleivora* Ashm.) *Ktavim* **9**: 281–5.

Swirski, E., Kehat, M., Gruenberg, S., Dorzia, N. and Amitai, S. (1967). Trials for the control of the citrus rust mite (*Phyllocoptruta oleivora* Ashm.) *Israel Journal of Agricultural Research* **17**: 121–6.

Tashiro, H. and Chambers, D. L. (1967). Reproduction in the California red scale, *Aonidiella aurantii* (Homoptera: Diaspididae). I. Discovery and extraction of a female sex pheromone. *Annals of the Entomological Society of America* **60**: 1166–70.

Tashiro, H. and Moffitt, C. (1968). Reproduction in the California red scale, *Aonidiella aurantii*. II. Mating behaviour and post-insemination female changes. *Annals of the Entomological Society of America* **61**: 1014–20.

Thompson, W. L. (1939). Notes on *Chaetanaphothrips orchidii* (Moulton) found attacking citrus fruit in Florida. *The Florida Entomologist* **22**: 65–9.

Thompson, W. L. (1940). Thrips attacking citrus fruits. *The Citrus Industry*, October pp 5, 8–9, 12–13, 17.

Tough, D. (1975). Citrus leaf miner on the advance. *Agricultural Gazette of New South Wales* **86**: 1:15.

Trammel, K. and Simanton, W. A. (1966). The nature and properties of spray oils. *The Citrus Industry* **47**: 25–7, 29.

Vergani, A. R. (1956). Mites of economic importance on crops in Argentina. *Revista di Investigaciones* **7**: 213–52. (Reviewed in *Review of Applied Entomology*, Series A, **44**: 181–2.)

Ward, K. M. and Johnston, C. J. R. (1937). Citrus red scale. Progress report on investigations, 1935–36. *Journal of Agriculture, Victoria* **35**: 397–416.

Waterhouse, D. F., Forss, D. A. and Hackman, R. H. (1961). Characteristic odour components of the scent of stink bugs. *Journal of Insect Physiology* **6**: 113–21.

Way, M. J. (1954). Studies on the association of the ant *Oecophylla longinoda* (Latr.) with the scale insect *Saissetia zanzibarensis* Williams. *Bulletin of Entomological Research* **45**: 113–34.

Willard, J. R. (1974). Horizontal and vertical dispersal of California red scale, *Aonidiella aurantii* (Mask.), (Homoptera: Diaspididae) in the field. *Australian Journal of Zoology* **22**: 531–48.

Wilson, F. (1960). *A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea*. Technical Communication No. 1, Commonwealth Institute of Biological Control, Ottawa, Canada. Commonwealth Agricultural Bureaux, Farnham Royal, Buckinghamshire, England, 102pp.

Woglum, R. S. (1923). The history of hydrocyanic acid gas fumigation as an index to progress of economic entomology. *Journal of Economic Entomology* **16**: 518–21.

Woodhill, A. R. (1929). The apple root weevil (*Leptops squalidus* Boh.) as a pest of citrus. *Agricultural Gazette of New South Wales* **40**: 813–7.

Woodhill, A. R. (1930). The citrus red scale. Progress report on fumigation and spraying experiments. *Agricultural Gazette of New South Wales* **41**: 125–30.

Woodhill, A. R. and Allman, S. L. (1927). The dicky rice weevil (*Maleuterpes (Prosayleus) phytolymus*) Olliff. *Agricultural Gazette of New South Wales* **38**: 791–9.

Zeck, E. H. (1932). Investigations on two white wax scales (*Ceroplastes*) as pests in Australia. *Agricultural Gazette of New South Wales* **43**: 611–16.

Zeck, E. H. (1934). White wax scale of citrus (*Ceroplastes destructor*). *Agricultural Gazette of New South Wales* **45**: 88–90.

POME FRUITS

Pome fruits pests

Pome fruits – apple, pear, quince and loquat – may be infested by a large number of insect and mite pests, many of which are common to both apples and pears, and some to quinces; the loquat has only two listed pests.

The major and minor pest species of pome fruits are listed in alphabetical order below.

ARTHROPODA

INSECTA

LEPIDOPTERA

Budworms	*Heliothis* spp.
Cluster caterpillar	*Spodoptera litura* (Fabricius)
Codling moth	*Cydia pomonella* (Linnaeus)
Fruit tree borer	*Cryptophasa melanostigma* (Wallengren)
Leaf case moth	*Hyalarcta huebneri* (Westwood)
Light-brown apple moth	*Epiphyas postvittana* (Walker)
Loopers	*Chrysodeixis* spp.
Orange fruit borer	*Isotenes miserana* (Walker)
Oriental fruit moth	*Cydia molesta* (Busck)
Painted apple moth	*Teia anartoides* Walker

HYMENOPTERA

Ants	Formicidae
Pear and cherry slug	*Caliroa cerasi* (Linnaeus)

DIPTERA

Queensland fruit fly	*Dacus tryoni* (Froggatt)

COLEOPTERA

Apple root weevils	*Perperus* spp.
Dried apple beetle	*Doticus palmaris* Pascoe
Dried fruit beetles	*Carpophilus* spp.
Fruit tree pinhole borer	*Xyleborus saxesini* (Ratzeburg)
Fruit tree root weevil	*Leptopius squalidus* (Boheman)
Fuller's rose weevil	*Asynonychus cervinus* (Boheman)
A green scarab beetle	*Diphucephala* sp.
Maize weevil	*Sitophilus zeamais* Motschulsky
Pitted apple beetle	*Geloptera porosa* Lea
Rice weevil	*Sitophilus oryzae* (Linnaeus)
Soldier beetle	*Chauliognathus lugubris* (Fabricius)
White fringed weevil	*Graphognathus leucoloma* (Boheman)

THYSANOPTERA

Plague thrips	*Thrips imaginis* Bagnall

HEMIPTERA

Apple dimpling bug	*Campylomma livida* Reuter
Apple leafhopper	*Typhlocyba froggatti* Baker
Apple mussel scale	*Lepidosaphes ulmi* (Linnaeus)
Black scale	*Saissetia oleae* (Olivier)
Cicadas	Cicadidae
Cowpea aphid	*Aphis craccivora* Koch
Dupla scale	*Duplaspidiotus claviger* (Cockerell)
Green vegetable bug	*Nezara viridula* (Linnaeus)
Long-tailed mealybug	*Pseudococcus longispinus* (Targioni-Tozzetti)
Mauve pittosporum scale	*Parlatoria pittospori* Maskell
Metallic shield bug	*Scutiphora pedicellata* (Kirby)
Pear root aphid	*Eriosoma pyricola* (Baker & Davidson
San José scale	*Comstockaspis perniciosus* (Comstock)
Soft brown scale	*Coccus hesperidum* Linnaeus
Spiraea aphid	*Aphis citricola* van der Goot
Woolly aphid	*Eriosoma lanigerum* (Hausmann)

ORTHOPTERA

Black field cricket	*Teleogryllus commodus* (Walker)
Wingless grasshopper	*Phaulacridium vittatum* (Sjöstedt)

ISOPTERA

Termites

ARACHNIDA

ACARINA

Bryobia mite	*Bryobia rubrioculus* (Scheuten)
European red mite	*Panonychus ulmi* (Koch)
A flat mite	*Brevipalpus* sp.
Pear leaf blister mite	*Phytoptus pyri* Pagenstecher
Two-spotted mite	*Tetranychus urticae* Koch

Apple pests

The apple is a 'cool-country' fruit which is grown commercially in New South Wales, mainly in the Orange, Batlow, Bilpin and Uralla-Kentucky districts. There are also many smaller producing areas, such as those near Sydney and in inland irrigation areas. The main varieties are Delicious, Granny Smith, Jonathan, Rome Beauty, Gravenstein and Crofton.

The development of the apple differs with variety and district but the following is an approximate phenological table.

Green tip	–	early to mid-September
Spur burst	–	late September to early October
Pink stage	–	early to mid-October
Full bloom	–	mid- to late October
Petal-fall	–	end of October

Harvesting of early varieties begins in late December. Mid-season varieties mature generally in January and February, but as late as March to early April on the tablelands. Late varieties are harvested right through the autumn, except for Granny Smiths in the Murrumbidgee Irrigation Area and around Forbes which may be picked to size for the culinary market in February.

The fungus diseases – apple scab, powdery mildew and bitter rot – continually menace the crop in some districts. The fungus disease control schedule, especially that for scab, must be precisely timed and applied. The insect pest control sprays are sometimes combined with the fungicide if the best times for applying both coincide and the materials are compatible. Dilute, semi-concentrate and concentrate sprayers are used for the application of sprays, but only the spray concentrations for dilute spraying are mentioned in this chapter.

An account is given on pages 92 to 116 of the pests of apple listed below.

INSECTA

LEPIDOPTERA

Codling moth	*Cydia pomonella*
Light-brown apple moth	*Epiphyas postvittana*
Budworms	*Heliothis* spp.
Painted apple moth	*Teia anartoides*

DIPTERA

Queensland fruit fly	*Dacus tryoni*

COLEOPTERA

Fruit tree root weevil	*Leptopius squalidus*
Apple root weevils	*Perperus* spp.
Pitted apple beetle	*Geloptera porosa*
Maize weevil	*Sitophilus zeamais*
Rice weevil	*Sitophilus oryzae*

THYSANOPTERA

Plague thrips	*Thrips imaginis*

HEMIPTERA

Woolly aphid	*Eriosoma lanigerum*
Spiraea aphid	*Aphis citricola*
San José scale	*Comstockaspis perniciosus*
Mauve pittosporum scale	*Parlatoria pittospori*
Apple mussel scale	*Lepidosaphes ulmi*
Apple dimpling bug	*Campylomma livida*
Apple leafhopper	*Typhlocyba froggatti*

ORTHOPTERA

Wingless grasshopper	*Phaulacridium vittatum*

ARACHNIDA

ACARINA

Two-spotted mite	*Tetranychus urticae*
Bryobia mite	*Bryobia rubrioculus*
European red mite	*Panonychus ulmi*

The following pests of apple are discussed in the sections on pests of other crops on the pages listed below.

INSECTA

LEPIDOPTERA

Cluster caterpillar	*Spodoptera litura*	251
Fruit tree borer	*Cryptophasa melanostigma*	141
Leaf case moth	*Hyalarcta huebneri*	26
Loopers	*Chrysodeixis* spp.	223
Orange fruit borer	*Isotenes miserana*	24
Oriental fruit moth	*Cydia molesta*	126

HYMENOPTERA

Ants	Formicidae	31
Pear and cherry slug	*Caliroa cerasi*	148

COLEOPTERA

Fruit tree pinhole borer	*Xyleborus saxeseni*	146
Fuller's rose weevil	*Asynonychus cervinus*	36
A green scarab beetle	*Diphucephala* sp.	229
Soldier beetle	*Chauliognathus lugubris*	149
White fringed weevil	*Graphognathus leucoloma*	281

HEMIPTERA

Cicadas	Cicadidae	137
Cowpea aphid	*Aphis craccivora*	234

ORTHOPTERA

Black field cricket *Teleogryllus commodus* 257

ISOPTERA

Termites 286

INSECTA LEPIDOPTERA

Codling moth *Cydia pomonella*

Importance and Distribution The codling moth has been known for many centuries as a pest of pome fruits. It was described and illustrated in 1635 by Goedaerdt in Holland. It was given the name 'codling moth' in England by Wilkes in 1747. Linnaeus, however, was the first to give it a scientific name when he described it briefly in 1758 as *Tinea pomonella*. In Australia, it was first recorded in Tasmania in 1857, in Victoria about 1885, in South Australia in 1885, in Sydney in 1887 and in Queensland in 1889 (Froggatt, 1901). It has been found in Western Australia on seventeen occasions between 1903 and 1958, since when it has not been reported. Prompt action has always eliminated it before an extensive infestation could develop.

Codling moth has caused enormous commercial losses in apples and pears in New South Wales, being most damaging in the warmer and drier inland districts. Up to the mid-1940s it could be expected to destroy almost the whole crop on untreated trees in districts which were favourable to it. Even on trees which had been well sprayed with the materials then available, losses up to as much as 30 per cent could be expected in bad years. The improvement in control has been due to the efficient methods and materials now available, and the enforcement of plant disease regulations so that the number of neglected trees is small in commercial pome fruit districts. Even so, failure to treat against the moth will still result in infestation. Crab apples grown as ornamentals, and usually left unsprayed in home gardens, often suffer heavy infestation year after year. Although today few people ever find a wormy apple in bought fruit, an experience only too common 40 years ago, codling moth is still the main pome fruit pest; control programmes in pome fruit orchards are primarily based on the need for protection against it. If present-day chemicals should fail to control codling moth and an alternative method of control is not available, the plight of the pome fruit industry could be grim.

Conditions for Infestation Districts with a warm dry spring, summer and autumn favour the codling moth. In such areas there can be three generations in a year, and almost every unsprayed fruit amongst late apples and quinces may be infested. Egg-laying occurs in late afternoon and requires a minimum temperature of about 16°C (Allman, 1928), so that warm spring weather favours an early build-up of populations.

Detailed studies by Geier (1964) on the population dynamics of codling moth at Canberra have emphasized the remarkable adaptation of this insect to its environment and its host plant. This adaptation allows it to multiply each year virtually to the limit of its supply of fruits for larval food.

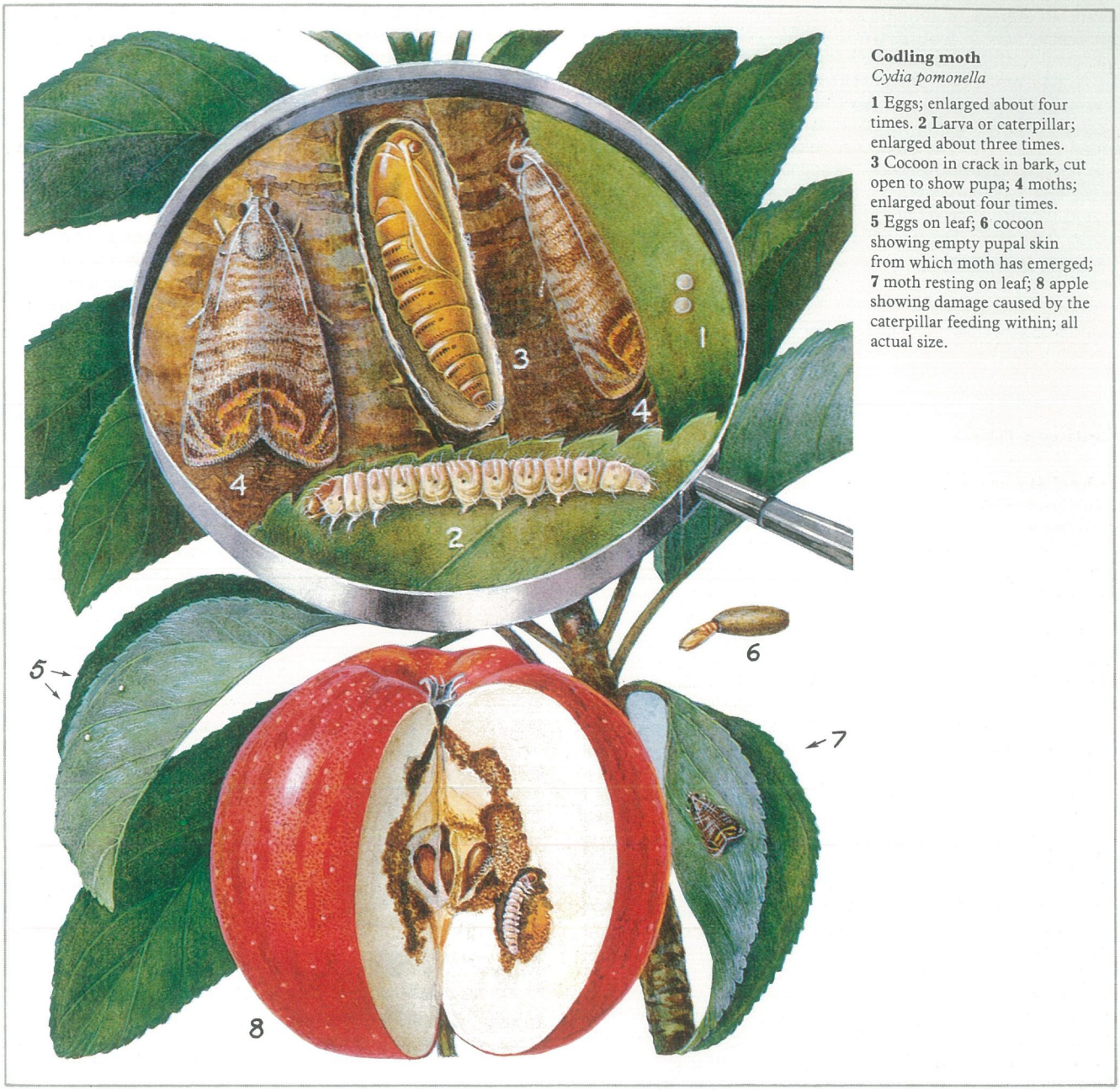
Plants attacked Codling moth is recorded most commonly on apples, pears, quinces and crab apples. In the United States it is a pest of some importance of walnuts, and may also infest them here. More rarely, larvae have been found feeding on fruits of peach, plum, apricot, cherry, orange, persimmon, pomegranate, crataegus, damson, and chestnut, and in oak galls, but essentially it is a pome fruit pest.

Description and Life History The adult is a grey-brown moth about 18 millimetres across the outspread wings with a conspicuous bright copper patch at the tip of each forewing. Occasional light copper specimens have been described by Allman (1931). The egg is round, flattened, semi-transparent and about the size of a pinhead. The newly-hatched larva is white and slender with a black head, and is about 1.5 millimetres long. The mature caterpillar is creamy with a pink tinge and about 18 millimetres long. When fully grown it pupates in a tough closely-woven cocoon. The pupa is dark brown and shiny.

The life cycles at Bathurst (Allman, 1928) and at Canberra (Geier, 1963a) are similar and may be taken as representative of the main apple-growing areas of New South Wales. There are two main generations of codling moth each year and usually a partial third generation. The broods of the different generations may overlap considerably. Allman defined a 'generation' as commencing with the egg stage and terminating with the adult or moth, although it may not be completed in the same crop-growing season as the eggs. The individual stages (eggs, larvae, pupae or moths) of any one generation may be referred to as a 'brood' and classified as 'first brood', 'second brood' or 'third brood' to identify the generation to which they belong. However, in the case of the overwintering larvae from the first, second or third generations, their pupae and the moths are referred to as 'spring brood' because pupation and emergence takes place in the spring.

A few of the first brood of caterpillars (that is, from eggs deposited by spring-brood moths) and most of the second brood enter diapause and overwinter or hibernate as full-fed mature fifth-instar larvae in cocoons. Those of the second brood, which do not diapause, develop to moths without hibernating and from these is produced a third brood which all overwinter. Occasional larvae from the overwintering populations do not pupate in the spring and may remain in the diapause condition through a second winter. The average overwintering period at Bathurst was about 190 days.

Codling moth cocoon on bark opened to show fully fed caterpillar. (Length of fully fed caterpillar about 18 mm)



Codling moth
Cydia pomonella

1 Eggs; enlarged about four times. **2** Larva or caterpillar; enlarged about three times. **3** Cocoon in crack in bark, cut open to show pupa; **4** moths; enlarged about four times. **5** Eggs on leaf; **6** cocoon showing empty pupal skin from which moth has emerged; **7** moth resting on leaf; **8** apple showing damage caused by the caterpillar feeding within; all actual size.

The overwintering caterpillars begin to pupate in about September, and the spring-brood moths start to emerge about a month later. The time of emergence of the spring-brood moths is influenced by a series of conditions: a conditioning regime in the autumn, a chilling regime in the winter and a dormancy-ending regime in the spring (Geier, 1963b). Dormancy in the overwintering caterpillars ranges widely from weak to strong.

The emergence of the first of the spring-brood moths from their cocoons early in October usually coincides with about the time the apples begin to blossom and may continue over a period of three months, reaching its peak in about mid-November – a little later in the cooler tablelands districts – with some emerging as late as mid-January. The eggs of these moths give rise to the first generation of the apple-growing season. The adults of the first generation produce the second generation of larvae which mostly overwinter, but a few non-diapausing individuals of this generation give rise to the small third larval generation. At Bathurst, Allman (1928) observed that moths (spring brood) from overwintering grubs could emerge at any time from mid-October to early January and that those of the next generation (first brood) could start appearing in mid-December, and continue to emerge until mid-February. The latter period has since been observed to extend into March, the peak period being in late January (Geier, 1963a).

Allman's (1928) life-history studies revealed that spring-brood moths deposited an average of 22 eggs and first-brood

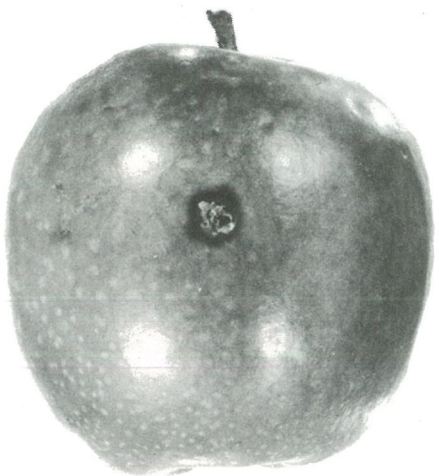
moths an average of 25. The highest number of eggs deposited per female was 78 by first-brood moths. The average length of the larval feeding period was 29 days for first-brood and 28 days for second-brood caterpillars. The average cocooning period for first-brood larvae was seven days and the average pupal periods were 25 days for spring-brood pupae and fifteen days for first-brood pupae. The incubation period for eggs of the first brood was ten days and of the second brood eight days. The life cycle of the first brood averaged 63 days. The average pre-oviposition period for spring-brood moths was four days and for first-brood moths three days. Spring-brood male moths lived for eighteen days and females nineteen days, while both sexes of the first brood lived for sixteen days.

About equal numbers of males and females are produced in all broods and mating, dispersal and egg-laying generally take place at nightfall. Moths spend most of their time in the crowns of trees when not in flight and probably find their food in the form of exudates from the fruit.

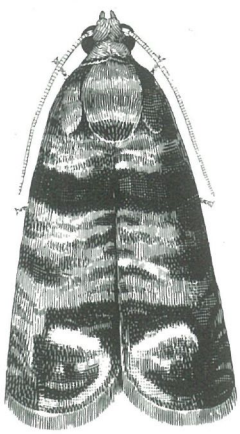
Eggs are laid singly on the fruits or on leaves and twigs close to the fruit. They are never found on trees which are not bearing fruit. If the egg is not on a fruit, after hatching the larva crawls to the fruit. Once on it, the larva will not leave the fruit although it may move about. When it finds a suitable spot, such as the calyx cup or some slight wound, the larva starts to penetrate. It first spins a mat of fibres. Some small pieces of skin are cut out and laid to one side before a hole is made that is big enough to accommodate the body. The larva then uses the first pieces of skin to cover the entrance hole and spins more thread to hold the cover in place. It has been seen to take up to two hours for the larva to work through the skin of a sound apple. Several larvae may enter a fruit, but usually only one, or occasionally two, reaches maturity as they are cannibalistic. The first-instar larvae normally feed near the surface of the fruit and will be found in a spiral-shaped cavity. The second-instar larvae bore radially to the centre of the fruit, where they enter the core area to eat seeds and moult. The third-instar larvae are mostly found in the seed chambers consuming seeds. In the fourth stage, the larvae seem to feed mainly on the pulp around the vascular bundles which surround the core and, by doing so, tend to hasten the ripening of the fruit. They form large frass-filled cavities around the core area which the fifth-instar larvae extend back to the surface of the fruit. At all stages larvae may return occasionally to the fruit surface, often pushing before them quantities of the brown sawdust-like frass which they discharge from their galleries at the original point of entry. In this way the original passages are enlarged repeatedly, until they cease to be used and new openings are cut by the maturing larvae in the side of the fruit for the disposal of frass.

Although newly-hatched larvae may be seen wandering during the day, the mature full-fed caterpillars move only at night. They begin to appear at dusk and are most abundant about two hours after dark, but become fewer as the night cools.

Mature larvae of the first brood crawl out of the fruit to seek suitable places on the branches or trunks of the trees to spin their cocoons. Those of the second brood leave the fruit to build their cocoons in sheltered positions, such as deep cracks and crevices in the wood of the trees, under bark scales, in tree crotches where debris accumulates, or in tree props. These larvae show a marked preference for sites offering the maximum cover with only small gaps to be walled off by the cocoon. When preferred sites are not available, the larvae may cocoon beneath small folds of bark on smooth limbs, in tree forks or in dry soil at the base of the trees. They never establish themselves in open or damp places. The rate of establishment tends to decrease with both the quality and quantity of shelter present on the tree.



Apple infested by codling moth.



Codling moth adult. (Length about 10 mm)

Injury Codling moth larvae feed only on the fruits of their hosts, and infestations may be very destructive due to the high proportion of fruit which becomes affected. Infested fruit is unacceptable for marketing.

Dispersal Distribution of codling moth to new areas is by the movement of infested fruit, or of cocoons in fruit containers, or in anything that provides a suitable cocooning place and has spent some time in the vicinity of harvested pome fruit from which full-fed larvae may emerge. Young nursery trees do not present any risk of introducing the moth to new orchards.

In a detailed discussion by Geier (1963a) it is concluded that codling moth is rather sedentary for a winged species, the female apparently spreading over no more than five to ten trees in most orchards. However, the males are more mobile, spreading as much as 180 metres (Proverbs *et al*, 1969). Infestation has been observed to be higher along orchard margins than further in, but the reason for this has not been satisfactorily explained.

Control measures

NATURAL Survival of the larvae is threatened by various factors in both the newly-hatched caterpillars and in the migrating stage of the full-fed grubs after they leave the fruit. In orchards under favourable weather conditions in Canberra, about one-third of the eggs laid by spring-brood moths resulted in successfully established larvae, and in other broods the ratio of three eggs to one deep entry generally applied (Geier, 1963a). In the newly-hatched stage the larvae fall victim to small predators, especially small mirid bugs which also attack the eggs. In the mature wandering larval stage, mainly before cocooning, they are preyed upon by earwigs, ants and other predators. The larva of a malachiid beetle, *Carphurus* sp., feeds on larvae and pupae (Allman, 1928; Geier, 1964). Native wasp parasites are bred from pupae and others kill larvae, but parasitization in natural shelter is rare. The egg parasite, *Trichogramma* sp., was found to kill about 30 per cent of eggs in autumn, but was insignificant at other times of the year. Adult moths are known to be killed by birds and spiders.

Geier (1963a) concluded that, despite their numbers, the moth's natural enemies did not appear to be capable of reducing its chances of survival significantly. He did not think the population dynamics of the codling moth would be affected seriously either by the disappearance of its existing natural enemies or by the introduction of new ones from outside Australia.

APPLIED Control of codling moth in New South Wales is compulsory under the *Plant Diseases Act* which requires thorough spraying of trees at regular intervals, the collection of fallen infested fruit at intervals of no more than seven days, the removal of infested fruit from the trees for immediate destruction of the infestation, and the treatment of any infested fruit or other codling moth-infested thing on the premises in such a way as to destroy the infestation.

In New South Wales the main methods of controlling codling moth have been the use of protective sprays and orchard sanitation, such as the destruction of infested fruit. As overwintering caterpillars are the only source of next season's infestation, the removal and destruction of cocoon shelters, such as loose bark, broken limbs, crotch litter and props, has been strongly recommended. The use of trap bands of hessian or corrugated cardboard around the trunks and strict packing-shed hygiene have also been advocated.

Lead arsenate was once the basis of a schedule of protective spray applications, at intervals of two or three weeks, starting at the calyx stage. Lead arsenate was sometimes supplemented with white oil, lime-sulphur or nicotine sulphate. These measures gave reasonable control in most years, but they were inadequate in seasons which were particularly favourable to the moth. Also the presence on the fruit of residues of lead and arsenic limited its export opportunities, and caused some concern about locally-marketed apples.

The advent of DDT in the mid-1940s heralded a new era in codling moth control. It had the residual toxicity to kill the larvae as they moved over the sprayed surfaces. Since then the occurrence of wormy fruit has become a rarity. Unfortunately, DDT had important side effects. Spider mites and, to a lesser extent, light-brown apple moth and woolly aphid showed spectacular population increases because DDT killed the natural enemies which had hitherto held them satisfactorily in check. As codling moth is not effectively controlled by natural enemies killing them with DDT did not have much impact on the moth population.

Then in the early 1950s resistance to DDT was reported in the Paracombe district of South Australia (Smith, 1955) and then in other States. In New South Wales DDT no longer gave a satisfactory degree of control (Lloyd, 1961).

Fortunately other insecticides had been developed for codling moth control and more have been developed since then. The most valuable of the insecticides replacing DDT have been azinphos-methyl, carbaryl and methidathion. Each of these also controls other pome fruit pests, but has the disadvantages of interfering with natural enemies. Both carbaryl and azinphos-methyl have the advantage over DDT that they can kill codling moth larvae for up to five or six days after the larvae have penetrated the apples (Hough, 1962).

The following recommendations applied in New South Wales at the time of publication.

- ☐ If the moth was abundant in the previous season, insecticides should be applied first at petal-fall and then at intervals of not more than fourteen days until late December, after which the interval may be extended to 21 days.
- ☐ If the moth was not numerous in the previous year, the first treatment should be applied within fourteen days of petal-fall, and then at 21-day intervals. However, the use of carbaryl sprays within 30 days of the full bloom period will cause thinning of apples and pears. Carbaryl may also cause russet damage to Delicious and Williams Favourite apples when applied before, during or shortly after near-freezing conditions.
- ☐ A minimum of four sprays is compulsory under the *Plant Diseases Act*, but usually five or six treatments with azinphos-methyl 0.05 per cent, or carbaryl 0.1 per cent, or methidathion 0.05 per cent should be applied thoroughly to every part of the foliage and fruit as specified above. All of these insecticides are very poisonous to bees so care is needed in their application to protect them.

PEST MANAGEMENT INVESTIGATIONS Although the present methods for controlling codling moth enable the fruitgrower to produce a crop of apples almost free from injury, an alternative lasting solution to the problem which is not so directly dependent upon chemical control is the ideal being sought. The development of resistance in insects and mites to once highly effective insecticides, and the mortality of beneficial insects, both parasites and predators, caused by the insecticides with good residual efficacy for codling moth control, highlight the urgency of the problem and create the need for more intensive, complex and expensive spraying programmes. Probably the most difficult problem to overcome in introducing pest management programmes with little or no dependence on chemical spray programmes, and which cannot in practice achieve the same high degree of fruit protection now taken for granted, is the consumers' demand for the blemish-free fruit which has been available for about the last 40 years. Educating the consumer to accept a somewhat lower standard of fruit protection as the price to pay for a much lower contamination of the environment by insecticides, and an alleviation of the insecticide resistance problem, will, therefore, have to have a very high priority in gaining support for the pest management programmes which can be investigated and developed.

In the mid-1960s a thorough appraisal of the problems of apple pests and their control was initiated in a programme of research by entomologists of the Departments of Agriculture of New South Wales, Victoria, South Australia and Tasmania and of CSIRO with funding from the Australian Apple and Pear

Board and the Australian Government. The project 'A Co-operative Programme of Research into the Management of Pest Insects in Pome Fruit Orchards of South-eastern Australia', the first co-operative venture of its kind in the history of economic entomology in Australia, aimed at testing the commercial possibilities of the integrated pest control concept, that is: 'a pest population management system which utilizes all suitable techniques (including chemical, biological, cultural and any other means of control) in a compatible manner to reduce pest populations and maintain them at levels below those causing economic injury' in apple orchards in a variety of environments in south-eastern Australia.

The programme of investigation (Lloyd *et al*, 1970) was undertaken in relatively isolated 1-hectare study blocks of trees at Bathurst and Canberra (tablelands localities in New South Wales); Leeton, N.S.W., and Tatura, Victoria (inland irrigation districts); Hastings, southern Victoria; Blackwood (Adelaide Hills), South Australia; and Grove (Huon Valley), Tasmania. The initial aim was to see what would happen when broad-spectrum insecticides were replaced by more selective materials. The only pesticides used were ryania, an insecticide made from the ground-up stems of a plant native to Central America and the Caribbean which had been shown to be moderately effective against codling moth and relatively non-poisonous to many other insects and to mites; captan and copper oxychloride to control apple scab; and dinocap to control powdery mildew. Significant damage to fruit by codling moth was observed in all orchards except Grove where it was almost non-existent. Woolly aphid ceased to be a troublesome pest in all study blocks. However, damage by orchard mites during the three seasons of the investigation was variable in the different study blocks – being insignificant in some, yet causing economic leaf damage in others – but this may indicate that the period for restoration of the desirable ratio between the mites and their predators should be longer than three seasons. Increased activity of natural enemies of woolly aphid and mites was recorded. Although light-brown apple moth was generally satisfactorily controlled at Bathurst, Canberra, Leeton, Tatura and Blackwood by its various predators and parasites, this was not so at Grove and Hastings where it was the most destructive pest observed during the investigation. Some trouble was also experienced at one time or another in one or more of the study blocks, in the absence of broad-spectrum insecticides, with plague thrips, apple dimpling bug, a looper, a budworm and San José scale.

The results demonstrated the necessity for continued intervention with pesticides against some of the pests and that natural enemies, when not affected by insecticides, can deal satisfactorily with woolly aphid and spider mites. Further investigations have had to be limited due to the withdrawal from funding by the Australian Apple and Pear Board and Australian Government because of economic conditions in the early 1970s. The entomologists have, however, continued investigations locally into such matters as the effectiveness of virus diseases for the control of codling moth and light-brown apple moth, the development of spray programmes using reduced concentrations of azinphos-methyl for codling moth control in order to allow beneficial insects to operate freely and the efficacy of predatory mites in controlling two-spotted mites. The loss of the obvious advantages offered by the large scale co-operative programme significantly affected the rate of progress, and a satisfactory integrated pest control programme for apple crops in New South Wales has not been developed yet.

Thwaite (1976) believes that integrated control of apple pests based on synchronizing insecticide applications with the occurrence of the moths may never be possible at Bathurst where trap catches over eight seasons indicated that 'the codling moth flight pattern was irregular and extended continuously over virtually the entire growing season'.

TRAPPING Various methods of trapping adult moths in the orchard have been tested over the years. Attractants such as wine and molasses have been used and black light traps enjoyed a short period of popularity.

Synthetic sex pheromone is now used in simple traps to catch males as a development of the original use of female moths in traps to lure the males. Madsen *et al* (1974), in investigations in South Africa, demonstrated a correlation between the number of male codling moths captured weekly and damaged fruit during the growing season and at harvest.

Light-brown apple moth *Epiphyas postvittana*

Importance and Distribution This native insect has become a serious pest of deciduous fruits in Australia. It is also an important problem in New Zealand and was fully defined by Dumbleton (1932). It was first recorded as a pest of apples in New South Wales by Olliff (1892) under the generic name *Cacoecia*, but was mentioned as a fairly important pest of pome fruits only after World War II. Growers were warned (Wason and Lloyd, 1949) to continue to use lead arsenate and not DDT for the control of codling moth on pears, as an increase in light-brown apple moth infestation on pome fruit resulted from the change from lead arsenate sprays to DDT. Lloyd (1960) confirmed the importance of this warning. Light-brown apple moth is a more important pest in the cooler districts of the tabeland areas of New South Wales than elsewhere. It is extremely important in some seasons in southern Victoria, and in Tasmania where its importance exceeds that of codling moth.

Conditions for Infestation Cool conditions extending well into the summer months favour this pest. Hot dry weather prevents its damage. In cool seasons it may breed through the summer and cause injury right up to the apple harvest. It is tolerant of low temperatures, and larvae develop at a slow rate on vegetation in the orchard during winter.

Plants attacked Light-brown apple moth feeds on a wide range of plants from many botanical families. It attacks almost all cultivated fruit crops, ornamental shrubs, most of the legumes, docks, capeweed, blackberry and wattles. Young nursery trees, because of their vigorous growth, are often heavily infested.

Description and Life History The adults are small buff moths, with a wing span of about 18 millimetres for the female, the male being slightly smaller. Viewed from above, the moth is bell-shaped when at rest. The adults shelter amongst foliage during the day and, when disturbed, make short quick erratic flights. At dusk they become active and fly amongst the trees.

The eggs are laid in flat masses, usually on the smooth upper surfaces of the leaves, or on stems or fruit; there are 20 or 30 eggs in a mass (Morris, 1966), overlapping each other like fish scales. They are pale greenish yellow when laid and are not easy to see on the leaf surface.

The newly-hatched larvae are pale yellow and very tiny. They wander actively over the plant surface, preferentially on the

Light-brown apple moth
Epiphyas postvittana

1 Eggs on leaf; **2** larva or caterpillar; **3** pupa; **4** adult moth; enlarged four times. **5** Eggs; **6** larva on citrus leaf; **7** empty pupal shell from which moth has emerged; **8** adult moth resting on leaf; **9** apple showing injury by the caterpillar feeding on the surface; **10** damage to citrus leaf by caterpillar; all actual size.

undersurfaces of leaves, before selecting a place on which to feed. The growing point of the lateral growth of fruit trees and other plants is also favoured. They roll the leaf surface with webbing to form a protective tunnel; they may web two leaves together, or a leaf to a fruit. They always feed under shelter. When disturbed they wriggle violently and move further into shelter, or fall to the ground, or hang suspended by a thread. When full-fed they are about 18 millimetres long with the body tapering slightly from the middle towards each end, and pale green with a brown head.

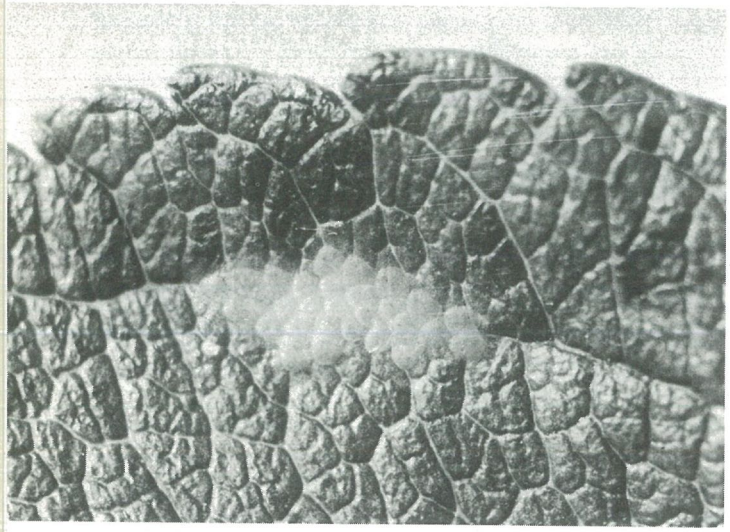
The pupa is about 10 millimetres long, tapering rather sharply towards the hind end, and enveloped in loose webbing generally in the rolled leaf where the larva was feeding.

The females live for about two weeks in summer and longer in cooler weather. They lay eggs in several batches; the first is laid two or three days after emergence.

The larva usually feeds for six or eight weeks, but in the cool months the time is greatly extended.

The pupal stage lasts for about two weeks and the full life cycle occupies two or three months in spring and summer. Generations overlap and all stages may be found almost throughout the year; even in winter some moths emerge. There is generally a sharp rise in moth activity, with the laying of many eggs, in the autumn when orchard spraying for other pests has ended. The autumn eggs hatch and the larvae feed on any available host. Capeweed on the orchard floor makes an excellent host at

this time, filling the gap until new growth appears on the fruit trees. In spring, larvae may migrate to the trees if disturbed by cultivation. Larvae hatching from eggs deposited on fruit just before harvest can feed on fruit in store; even in cold store the damage may continue at a reduced rate.

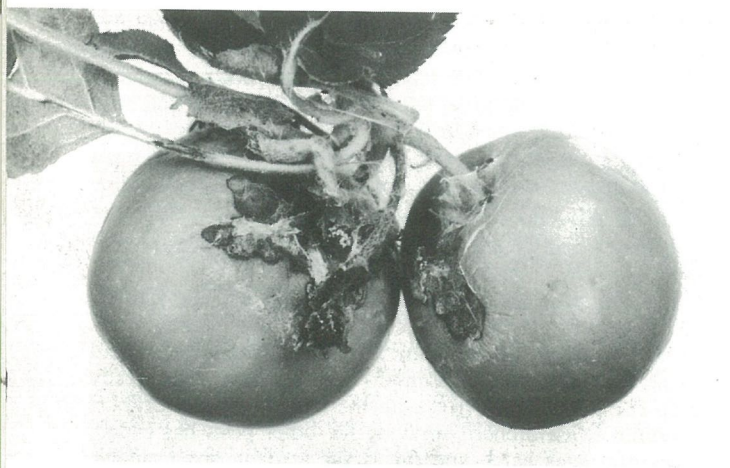


Light-brown apple moth eggs.

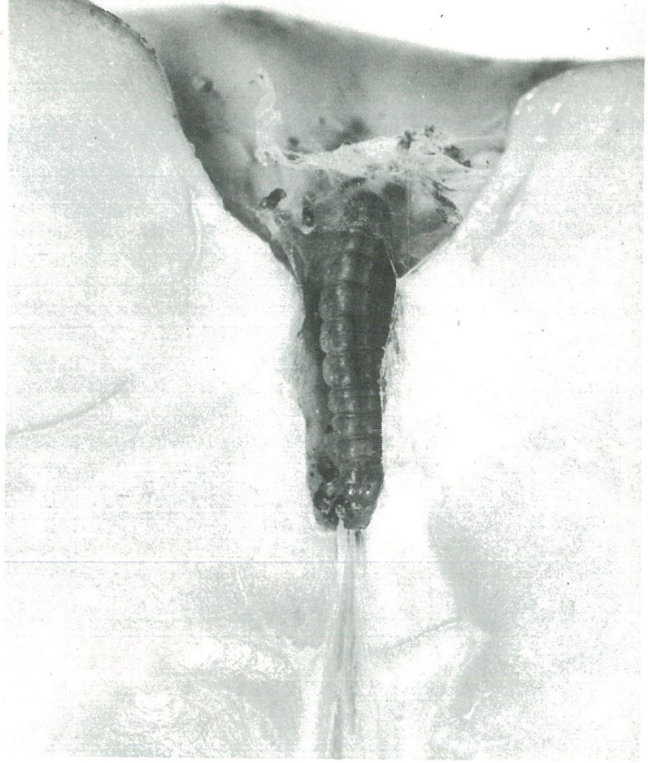
Injury Injury to young leaves may be of consequence on newly-planted trees, causing some check in growth. On mature trees larvae feeding on the leaves is unimportant, except when a leaf is webbed to a fruit and the fruit itself may be grazed.

Feeding on growing apples results in large irregular blemishes which, although only shallow, are very injurious. They often form a callus and, after rain, admit rotting organisms. Even if no rot develops, the blemish causes down-grading or rejection from the market.

A common site of injury on apples is at the stem end where it is easy for the grub to spin a web and feed in the stem cavity under shelter. Short-stemmed clustered varieties like Jonathan and Sturmer apples are more susceptible to this injury than are the longer-stemmed varieties like Granny Smith (Lloyd, 1960). Occasionally, larvae may enter apples at either the stem or the calyx end.



Light-brown apple moth injury to apples.



Occasionally a light-brown apple moth larva enters the apple at the calyx or the stem end.

Dispersal Both adults and larvae can move about on and to nearby trees in an orchard. In the spring there is an important movement of larvae that have overwintered on weeds under the trees. When larvae find themselves crowded on the tips of shoots on orchard trees they tend to scatter and feed on the surface of fruits causing heavy damage (Geier, 1965). Moths can fly, but dispersal of the adults is limited (Geier *et al*, 1967). In mixed habitats where there are orchards and areas of native vegetation, however, moths migrate in early summer from the ageing foliage of native plants to the new fruit tree foliage, and multiply in the orchards for a few months before returning to native hosts in the autumn. The moths may also move in this way between orchard trees and windbreaks.

Control measures

NATURAL Natural enemies of the egg, larva and pupa can maintain a rigid control on the upsurge of populations. The actual numbers of light-brown apple moth grubs are far below those that could be supported by the food available; this is due to the combined action of a wide array of parasites and predators, assisted in certain instances by at least one pathogen (Geier, 1965). The disturbance in the balance of natural enemies by orchard spray programmes is accepted as being a major factor in the occurrence of damaging infestations of light-brown apple moth on fruit crops.

Lead arsenate applied to control codling moth was effective against light-brown apple moth and harmless to many of its natural enemies. The change to DDT, and subsequently to azinphos and carbaryl, has introduced treatments which are harmful to many of the natural enemies of light-brown apple moths. However, although the insecticides are severe in their effect on useful insects during seasonal spraying operations, there is good evidence that these sprays do not eliminate the natural enemies as they increase in numbers each year after the

spraying programme has ended. Morris (1966) further reported that the egg parasite, *Trichogramma* sp., was often abundant in Victorian orchards in autumn. Many parasites were bred from overwintering larvae collected in orchards. The most numerous were two tachinid flies, *Voriella* sp. and *Zosteromyia* sp., and two wasp parasites, *Apanteles* sp. and *Xanthopimpla* sp. Spiders kill many of the larvae – both young and older. Morris also reported the infection of larvae by a virus.

APPLIED Because the larvae always feed under shelter, spraying must be very thorough. Spraying for codling moth gives excellent control of light-brown apple moth if done with care and according to the recommended timing. The materials recommended are the same for both pests: carbaryl 0.1 per cent, or azinphos-methyl 0.05 per cent, or methidathion 0.05 per cent.

Winter breeding in the orchard weeds and cover crops can be reduced by growing heavy crops of cereals which are not favoured for infestation.

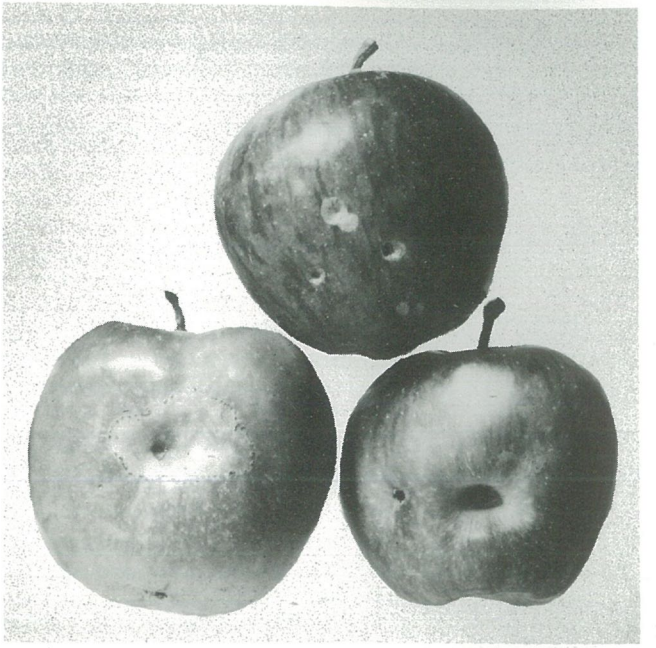
Budworms *Heliothis* spp.

In moist springs these caterpillars may be plentiful on herbage growth on the orchard floor, then migrate to the trees when herbage dries. They can be yellow, green, buff or red-brown in colour, with a variable number of black or brown markings or with broad longitudinal stripes. They bore into the newly-set fruitlets and, if these do not fall, they will be deformed at maturity by deep surface depressions with brown scar tissue at the bottoms. On young trees, the caterpillars may cause harm by feeding on leaves and shoots. Suppression of herbage growth near the trees, by the end of September, avoids the risk of this type of budworm attack. However, in some seasons the moths lay eggs on deciduous fruit trees in spring, and infestation and fruit damage follow.

Control measures Spraying with endosulfan 0.07 per cent is effective against budworms of fruit trees.

Budworms are important pests of many other crops, and are described in more detail on page 219 under Bean Pests.

Budworm damage to newly-set fruits.



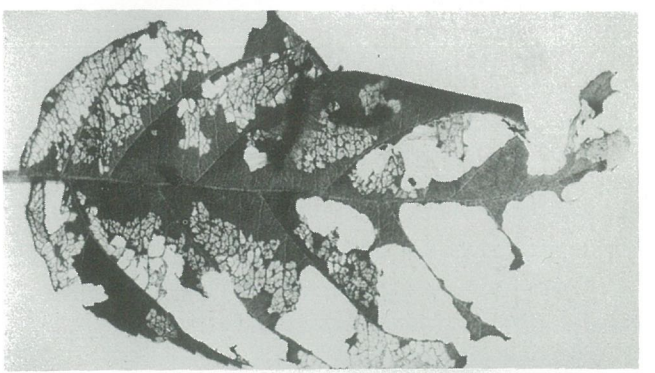
Mature apples which were damaged as newly-set fruits by budworms.

Painted apple moth *Teia anartoides*

Caterpillars of the painted apple moth feed on a wide variety of plants. They are sometimes pests of apples, apricots, cherries and other garden plants.

The full-fed caterpillar is about 3 centimetres long and densely covered with brown hairs with four tufts or 'brushes' of white hairs on its back, and a pair of black horn-like tufts projecting from its head. When full-fed, the larva spins a flimsy silken cocoon on or near its food plant.

The male moth measures slightly less than 2.5 centimetres across the outspread wings – dark brown forewings marked with black, and orange hindwings with a broad black outer band. The female moth is wingless and thickly covered with short brown hairs. The legs and antennae are rudimentary. After emergence the female usually remains on the outside of the cocoon and deposits the tiny (less than 1 millimetre across) glossy white almost-spherical eggs there.



Apple leaf damaged by painted apple moth caterpillars.

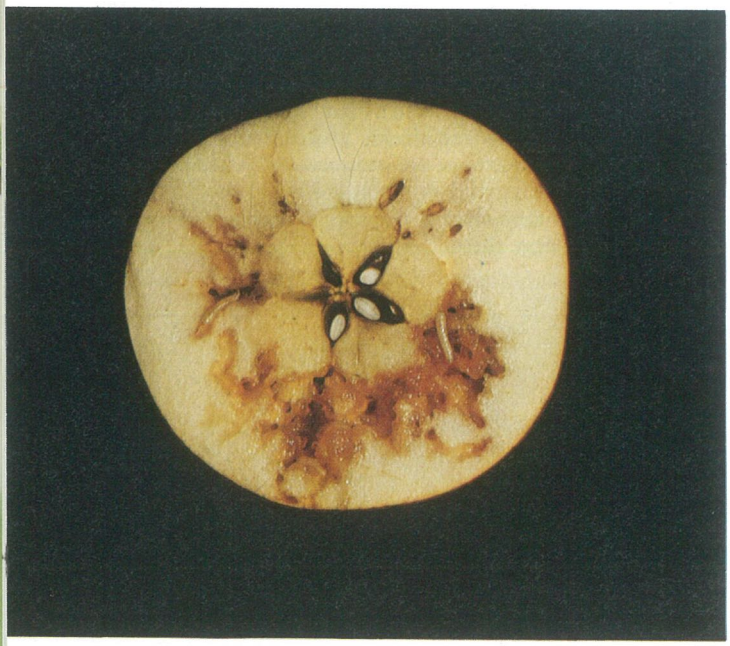
Grazing of small areas of the leaf surfaces results in small brown window panes which are later disintegrated to form holes. Green fruits are also grazed. It is more usual for only single trees to be infested.

Control measures The caterpillars can be controlled by spraying with carbaryl 0.1 per cent.

DIPTERA

Queensland fruit fly *Dacus tryoni*

Fruit fly is not a pest of great importance in apples in New South Wales. The districts where apples are grown commercially are not very suitable for it. However, non-commercial trees in any of the coastal districts are likely to bear infested fruit. In the few commercial apple orchards in districts susceptible to fruit fly, the incidence is usually low because the spray programmes against codling moth and light-brown apple moth also provide good control of fruit fly. Occasionally it may be necessary to apply special measures against fruit fly late in the season. Where they are exposed to the fly, apples are quite susceptible but the reaction of the fruit differs among the varieties. In the early soft varieties, infestation is followed quickly by breakdown and rotting of the fruit until it is squashy and brown. In later varieties with a denser cell structure, maggot development is slower and small larvae spend a considerable time tunnelling, leaving only fine light brown tracings to show their movement, and without extensive breakdown. This is rather typical of the Granny Smith variety.



Apple infested by Queensland fruit fly. P.R.I., Dept of Ag. Vic.

Control measures If routine pest control programmes in a commercial orchard fail to control the fly, or where a humid summer leads to unusually high fly numbers, special applications of protein hydrolysate-maldison bait spray may be needed. These should be applied very lightly to the outside foliage of the trees at weekly intervals during the danger period. The baits are described for Queensland fruit fly under Citrus Pests on page 34.

Home-garden trees may be protected from maggot infestation by using sprays of either dimethoate or fenthion 0.06 per cent applied eight weeks and seven weeks before the likely ripening date. These treatments kill the tiny maggots as they hatch from the eggs, but they do not prevent 'stinging'. The 'stings', where the eggs have been inserted into the fruit, show up as black marks on the skin. This blemish does not prevent the fruit from being edible.

Queensland fruit fly is more fully described under Citrus Pests on page 31.

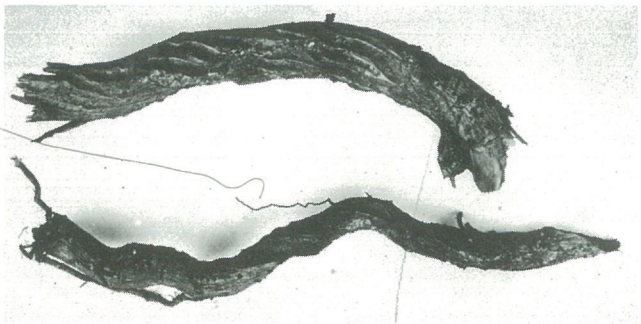
Queensland fruit fly 'stings' (oviposition sites) in apple.

COLEOPTERA

Fruit tree root weevil *Leptopius squalidus*

This weevil, the female of which is about 2 centimetres long and the male somewhat smaller, is a common and serious pest of apple trees, especially in coastal districts and parts of the Southern Tablelands. It attacks other deciduous fruit trees and citrus. The growth of the tree is usually affected uniformly in citrus, but growth in pome and stone fruit trees may be affected on one side only while the other side continues to develop normally. The damage is caused mainly by the larvae which feed

on the roots, gouging out deep furrows and inducing rotting that gravely harms the tree. The adult weevils feed on the foliage and buds, but the harm done by them is only slight.



Roots damaged by fruit tree root weevil larvae.

On deciduous trees the grubs feed on roots in the sub-soil. If the surface soil is shallow and of poor quality, the tree may die in a short time. If the tree is in good deep soil, the grubs will be working more than 30 centimetres from the surface and the tree may survive for years and appear to make a recovery in good seasons. Ultimately fruit tree root weevil damage results in the death of the top branches. Quite strong growth of the lower limbs while the top of the tree is dying is characteristic. Orchardists often diagnose the trouble as 'wet feet'. The damage by root weevil is more extensive than is generally realized and, if only surface roots are examined, no grubs will be seen. If the top of a tree is dying, digging down to about 60 centimetres below the crown will probably show severe furrowing of the main tap-root, and often lateral roots completely hollowed out and reduced to cylinders of dead bark filled with frass.

The weevils cannot fly. They emerge from the soil between late August and November, and crawl up the trees to lay eggs. On hatching the young larvae drop to the ground.

Control measures Control can be achieved by spraying with DDT 0.1 per cent in spring when the weevils are emerging.

The use of trap bands of flyscreen wire around the trunks of trees will give valuable information on the presence of adult weevils in the spring. Use a piece which is wide enough to be tied to the trunk and turned out and down so that the weevils can not find their way out or around the edge.

This pest is described more fully on page 39 under Citrus Pests.

Apple root weevils *Perperus* spp.

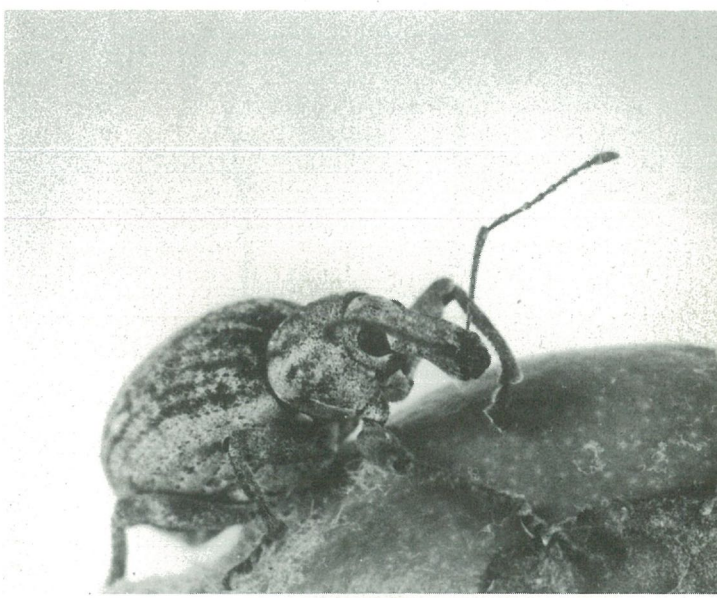
Until recently when it was found that the speciation could not be substantiated these weevils had been identified as fruit tree bud weevil, *Perperus vermiculatus* Lea, feeding as adults on developing buds and tender foliage of apple trees, and apple root weevil, *P. languidus* Erichson, feeding as larvae on apple tree roots. In each case the adult weevils were grey-brown and about 10 millimetres long.

The adult weevil attack on buds and foliage has in some seasons been serious in the Orange district. It can cause severe set-back to young trees, but has been of no importance on trees over five years old.

In the Orange district it was observed that the adults emerged from the soil in early September and fed on buds and foliage for six to eight weeks. Although most commonly reported on apples, they also attack pears and peaches. Feeding is mainly at night although some has been observed in the daytime; the weevils usually hide by day around the trunks or under trash. They do not fly, but can crawl rapidly, and infestation can spread quickly through a block of trees.

The weevils usually attack the terminal buds and leaf clusters first, and then work back along the twig, with, occasionally, every bud on a young tree being destroyed. When the buds are bursting in September or early October serious damage can be done, but once growth is well under way even heavy feeding by the weevils may occur without serious ill effects (Lloyd, 1952).

Attack by weevil larvae on apple tree roots has been studied at Batlow (Lloyd, unpublished information). Symptoms of weevil attack noted there have included considerable diminution of lateral growth on previously vigorous and productive trees, formation of small leaves and small fruits of little or no value, die-back of limbs and complete loss of productivity. Some trees were stunted throughout their lives so did not develop the spectacular die-back symptoms of trees that had grown well initially. Affected trees had severely pitted and channelled roots, with almost total absence of feeding roots. Apple root weevil grubs were found close to damaged roots and adults have usually been plentiful on herbage in blocks of damaged trees during October and November. Where apple root weevils were excluded from certain experimental areas growth of the trees there was superior to that of trees in areas where the weevils were present.



Apple root weevil. (Length about 10 mm)

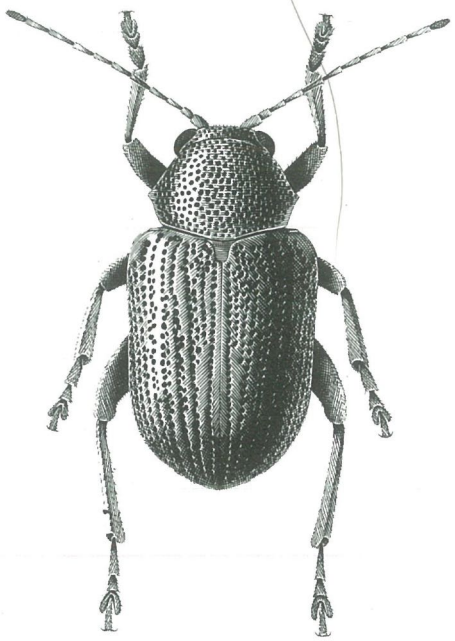
Control measures The current recommendation is to spray with DDT 0.1 per cent before egg-laying commences, one to two weeks after adult emergence in warm weather, or longer in cool weather.

Pitted apple beetle *Geloptera porosa*

These beetles have been recorded by Froggatt (1920) swarming on to apple trees and gnawing patches of skin from the ripening fruit. They have also been seen eating the foliage and twigs of young citrus trees. They are of only occasional importance and have not been seen further inland than the coastal districts.

The beetles are small, about 6 millimetres long, reddish brown and thick-set. The surfaces of the head, thorax and wing covers are densely pitted. The eyes are black and project from the sides of the head. The legs are yellow-brown and the hind legs have swollen thighs which are metallic yellow.

Control measures Spraying with carbaryl 0.1 per cent is suggested.

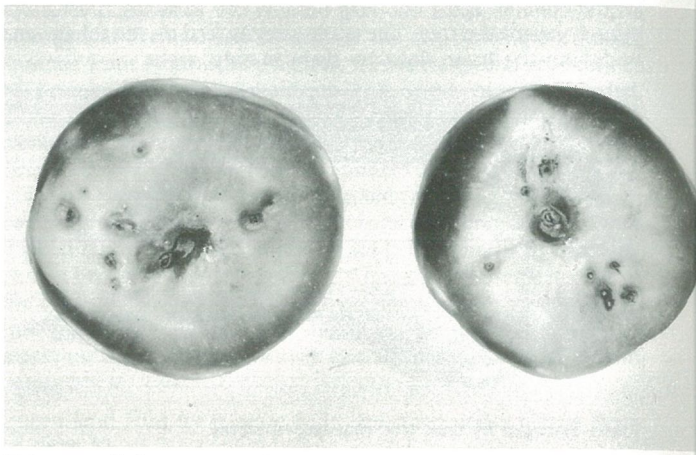


Pitted apple beetle. (Length about 6 mm)

Maize weevil *Sitophilus zeamais*
Rice weevil *Sitophilus oryzae*

An unusual type of injury may be seen occasionally in late summer when maize weevils fly from infested stored grain to a nearby orchard with ripening apples. The factor which initiates such a flight has not been determined. The weevils lay eggs on the apples as they would on grain; the female drills a hole with its snout and then puts in an egg. When the weevils are numerous many apples can be ruined. The fruit can also be damaged when stored close to weevilly grain. A severe infestation in the field has been described by Watt (1965).

Rice weevil, originating from stored wheat, has been recorded by Watt (1965) damaging stored Granny Smith apples.



Maize weevil damage to apples.

THYSANOPTERA

Plague thrips *Thrips imaginis*

Importance and Distribution This native species has increased to plague numbers during spring and damaged various crops at intervals over at least 70 years. Thrips outbreaks have been reported from most States. Reduced setting of apple crops can be caused by thrips feeding in the blossoms but other factors such as late frost, unusual heat waves at flowering, a dry spell before blossoming, or absence of bees may contribute. A detailed study of *Thrips imaginis*, with special reference to the cropping of apples, has shown that the losses in a season (as in the record thrips year of 1931) were due to a combination of factors, of which thrips damage was only one (Evans, 1932). He further stated that the primary effect of an infestation in apple orchards is a reduction of the crop and the secondary effect is to establish State-wide fluctuation of crops. Practical experience of growers and other observers supports the opinion that, in some areas with some varieties, even a small number of thrips per blossom can bring about a significant reduction in cropping. Investigation in the Murrumbidgee Irrigation Area has indicated that the occurrence of four or five thrips per blossom on Granny Smith apples warrants the application of control measures (Wason, unpublished). This practice has been followed by many growers in the area for many years with satisfactory results. Plague thrips has been recorded in all Australian States. According to Evans, plague thrips is undoubtedly the species responsible for damage to apple blossoms.

Conditions for Infestation The first requirement for a spring 'plague' is the presence of abundant thrips early in spring, brought about by above-average rainfall in the autumn and a mild winter to allow survival of the hibernating thrips. If such conditions are followed by a dry sunny spring with abundant flowers on such plants as capeweed and Paterson's curse, the

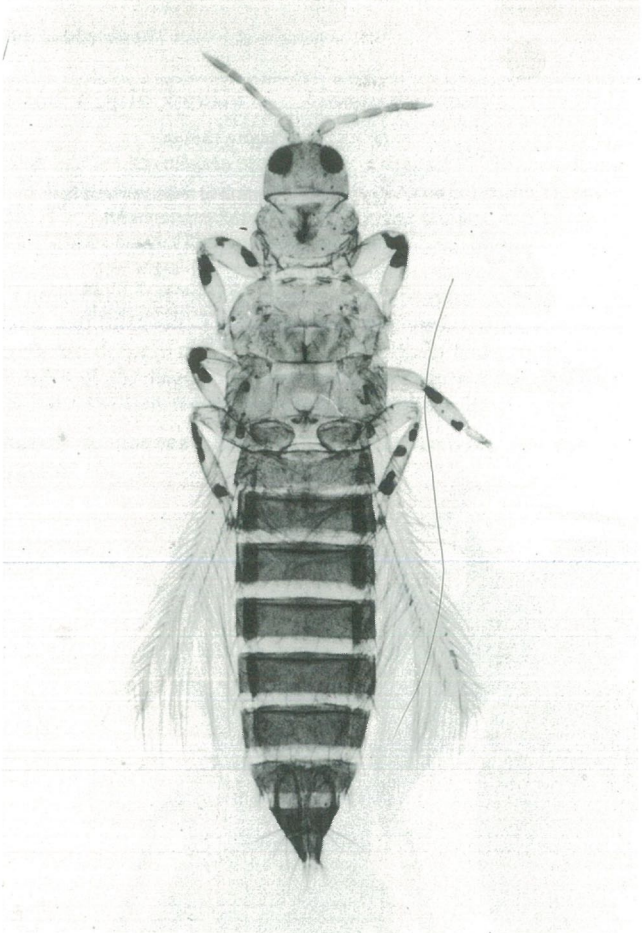
Plague thrips
Thrips imaginis

1 Egg; **2** first-stage nymph; **3** second-stage nymph; **4** prepupa; **5** pupa; **6** adult thrips; all enlarged about thirty-five times. **7** Blossoms showing thrips on petals; actual size.

stage is set for an outbreak of thrips, and heavy infestation of apple blossom can be expected. A spring with alternating warm and cold periods has the effect of bringing the thrips generations into line. Warm days produce the well-known rises in active populations when millions of the tiny insects appear suddenly, and often disappear next day in a cold change. The short periods of intense thrips activity account for damage to apple blossoms and help to explain why a few days difference in flowering between blocks of trees, even of the same variety, can result in marked differences in injury. Heavy showers of rain reduce thrips numbers, sometimes spectacularly. The rain kills thrips in flowers, and it packs surface soil which prevents the emergence of adults from pupae.

Plants attacked Plague thrips is mainly a blossom feeder, although it does attack some young foliage. When it is numerous it may be found in every sort of flower, even those of grasses and weeds. In the orchard, the flowers of the ubiquitous capeweed are always infested and these may be used for sampling to predict an attack on economic crops.

Description and Life History The adult females are narrow-bodied, light brown or grey, and about 1.2 millimetres long. The males are smaller and yellow. Both sexes have two pairs of narrow delicate wings, fringed with long hairs, which lie along the back when not in use. They are described by Vevers Steele (1935).



Plague thrips. (Length about 1.2 mm)

The colourless eggs are deposited in the tissue of petals, sepals and blossom stems, as well as in the stamens, pistil, calyx cup and young leaves. As many as 150 eggs have been found in a single blossom stalk. The tiny nymphs which emerge are yellow with red eyes. They feed in the blossom mostly on the stamens and pistil, and on the petals. When full-grown they crawl down the plant, enter the soil to a depth of about 5 centimetres, and change to prepupae and then pupae.

The time from egg to adult may vary from about ten days to more than a month, depending largely on temperature. The emerging females are yellow but they begin to turn brown in two or three days, and their abdomens distend as they feed.

Plague thrips are present in varying numbers throughout the year, but only in the spring are they of significance in the apple orchard.

Injury Nymphal and adult thrips have mouthparts adapted for piercing plant surface cells. Petals and anthers turn brown and shrivel when thrips feed on them. Where thrips enter blossoms before they open, normal opening may be adversely affected. Feeding and egg-laying on the pistil may cause it to wither.

Dispersal Adult plague thrips are extremely active and fly readily. They can spread within the orchard, and be carried by wind for long distances. However, they travel mainly between the orchard weed cover and the trees.

Control measures

NATURAL No specific parasites of plague thrips are known. It is probable that predators take a toll of the population, but it is unlikely that their influence is comparable in extent to that of the weather.

APPLIED Direct measures for the control of plague thrips are based on DDT applied at the first indication of a dangerous increase in population and repeated at four to five day intervals. The success depends on the residual effect of DDT keeping the flowers free enough from thrips for pollination to occur in the few days involved. It is usual for emulsifiable concentrate of DDT 0.1 per cent to be applied at the pink stage if thrips numbers reach six or eight per blossom or if thrips are looking dangerously numerous in capeweed. Spraying in full bloom should be avoided because of the danger to bees; while any blossom is on the trees, spraying should be done in early morning or late evening.

Apple blossom damaged by plague thrips, and undamaged blossom.

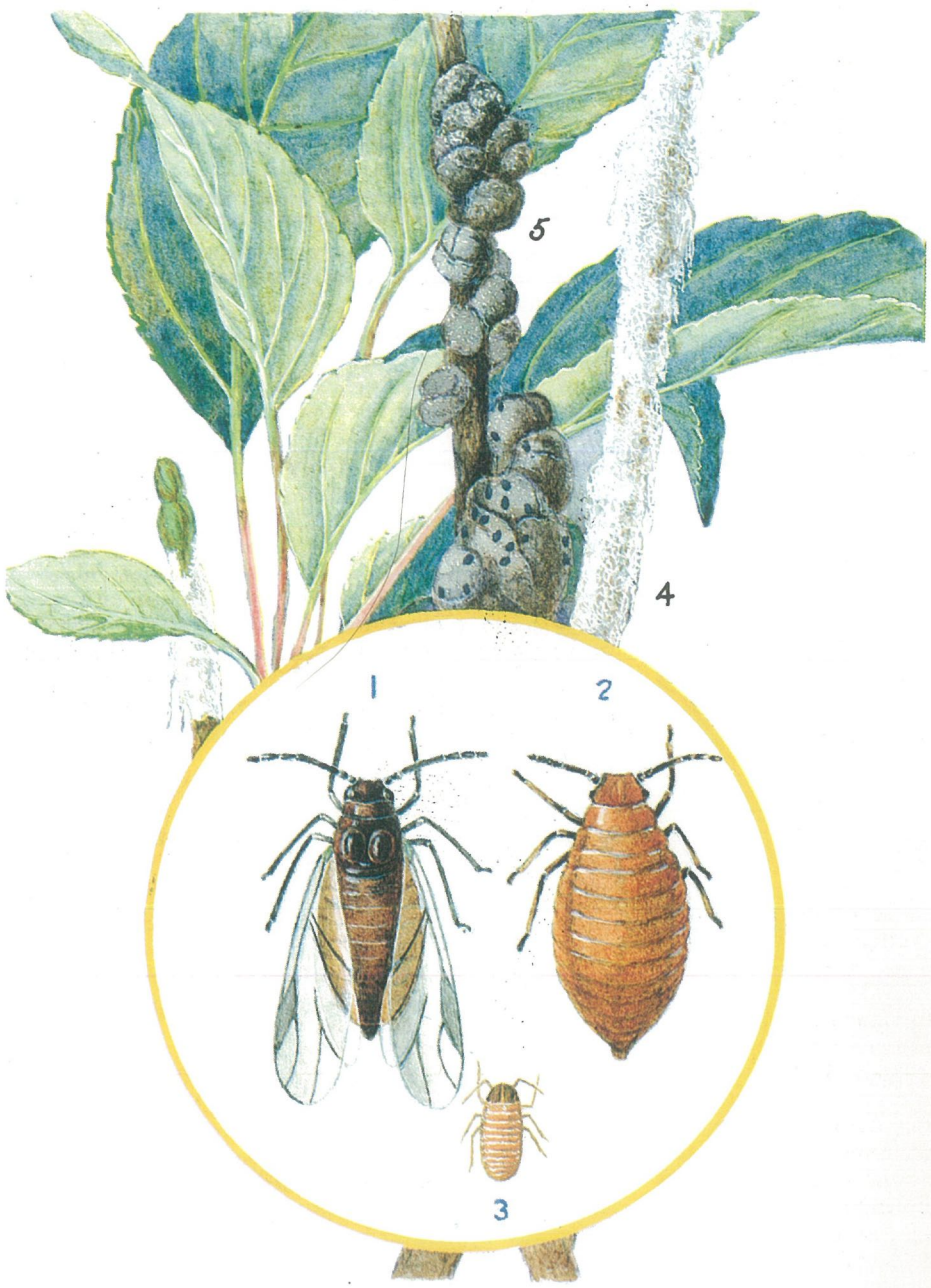
Woolly aphid *Eriosoma lanigerum*

Importance and Distribution This insect occurs throughout the apple-growing countries of the world and in all States of Australia.

It can be extremely damaging to trees as it may reduce cropping, lower the quality of the fruit, and be a nuisance to pickers. It thrives best in cooler and more moist apple districts, and is generally most objectionable in seasons when the growing conditions are best.

Conditions for Infestation Woolly aphid is most abundant in thick vigorous trees with shady interiors, or in trees shaded by windbreaks. Low humidity and temperatures above 27°C are unfavourable to it, but low temperatures have little effect apart from slowing down its rate of development.

Plants attacked In New South Wales, woolly aphid is almost exclusively a pest of apples although it sometimes infests shrubs,



Woolly aphid
Eriosoma lanigerum

1 Winged female; **2** wingless female; **3** young larva, first stage; all enlarged about eighteen times. **4** Apple twig showing woolly covering of aphids; **5** twig showing swellings caused by the aphids; the lower swellings carry parasitized aphids; all actual size.

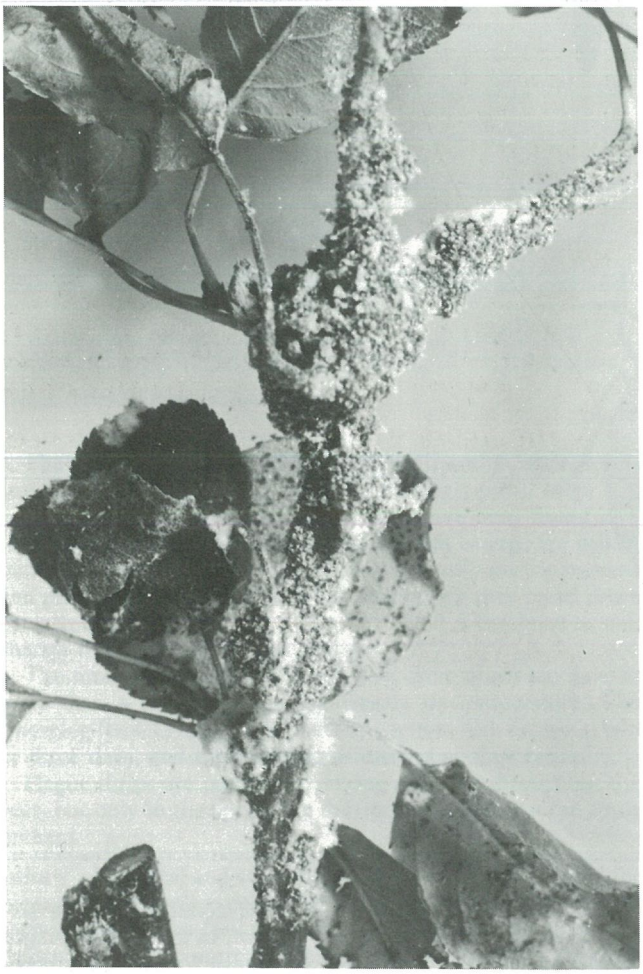
such as crab apple and hawthorn, and very rarely pears. It has been seen on the exposed roots of liquidambar growing close to infested apples.

Description and Life History The forms found on the apple trees are mostly females. The adults are nearly all wingless, globular in shape, purple-brown and usually covered with long white cottony threads secreted from pores on the body. These threads form a loose tangled mass over the active colonies. A white powder is also produced which usually covers the insects. Globules of clear honeydew are exuded which drip over foliage and fruit, and support a growth of black sooty mould.

The wingless females each produce about 100 living six-legged larvae that are light brown and flat. In the autumn winged females appear. In Australia, the number of winged females produced in autumn appears to have no significance other than a reduction of the aphid population on the apples. Overwintering depends on the survival of immature aphids on the above-ground parts of the apple trees and on the roots of susceptible stocks. Some migration from tree to roots takes place in early winter with a return to the above-ground parts of the tree in spring, but survival of the population depends mostly on young aphids in cracks and crevices of old wood. A few sexual forms are produced on the apple, but they do not feed and their eggs

rarely hatch. In North America, the winged females migrate to elms and produce overwintering forms. This cycle from apple to elm was not seen in any other country (Dumbleton and Jeffreys, 1938).

Injury Colonies of woolly aphids, which may first appear on mechanically damaged parts of the tree, develop on twigs and branches of the apple and on the roots of susceptible stocks, and feed by piercing the bark and sucking sap. Small groups may occur in the stem cavity of fruits. The feeding of the aphids on shoots produces smooth swellings that later become cracked and rough, and buds are destroyed. Heavily infested trees become gnarled and lumpy, and productive wood becomes greatly reduced. Copious honeydew encourages sooty mould which interferes with the tree's growth by cutting off light, causes some fruit-fall, and soils the fruit. It also affects the colouring of red varieties. The honeydew is a nuisance to people working in infested trees.



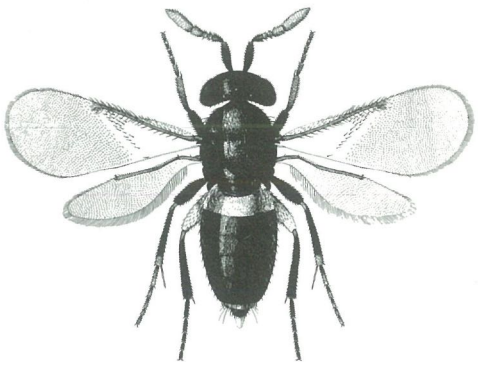
Woolly aphid infestation of apple twig.

Dispersal Movement from infested to clean trees is slow, and is mostly due to larvae which move readily on the twigs and foliage of their own trees and become wind-borne or carried by birds, insects or man. The winged aphids of autumn appear to have no significance. Most orchard infestations probably arise from aphid colonies on young trees from the nurseries.

Control measures

NATURAL Several enemies prey upon the woolly aphid – ladybirds, lacewing larvae and syrphid fly larvae – but the parasite, *Aphelinus mali* (Haldemann), is especially important. This tiny wasp was introduced to Australia in 1923 (Wilson, 1960). It continually contributes to the suppression of the pest, but has unfortunately been reduced in effectiveness by the general use of DDT and other modern chemicals. It sometimes seems to die out but it then reappears. Re-introduction of *Aphelinus* to a district has only rarely been necessary. The occasional infestations of woolly aphid on hawthorn are valuable for maintaining the *Aphelinus* population. Hawthorn often grows near apples in New South Wales and is not sprayed.

In the spring there appears to be a delay between the appearance of the active woolly aphid colonies and of the parasites, but actually the wasps emerge from dead aphid bodies in September at the same time as the colonies become active. Parasitized aphids lose their woolly covering and go black, but not many are seen until mid-summer. They are more abundant in autumn. Empty black aphid body-shells, with the round holes through which *Aphelinus* has emerged, are a guide to the activity of the parasite in the orchard. Conservation of the wasps is possible by collecting aphid-infested twigs early in winter, before spraying, and storing them in a shed away from birds. In early spring the twigs should be placed in trees known to be aphid-infested, because natural spread of the wasp is slow. While this exercise is recommended, it is probable that winter sprays, such as petroleum oil or lime-sulphur, do not do much harm to the parasites inside dead aphid bodies; the more modern insecticides may be harmful to them.



Aphelinus mali, parasite of woolly aphid. (Length about 1 mm)

APPLIED Control of the root-infesting form of the woolly aphid by the use of resistant stocks has been practised successfully for many years. Northern Spy is the best known variety. Other stocks of the Malling-Merton series are also valuable.

Northern Spy stocks were used almost exclusively in New South Wales from the early 1900s to the early 1940s. Because of their immunity to woolly aphid and ease of propagation, only very few apple trees were worked on any other stock. As other methods of control of woolly aphid improved, renewed interest was shown in using seedlings for stocks because of their vigour and the longevity of trees worked on them.

Later, interest was stimulated in close hedgerow planting, a type for which Northern Spy is used.

Whatever the type of stock, there will always be a need for some control by spraying or by some other direct method. If susceptible stocks are used, control on the aerial parts of the tree

becomes more difficult. Lloyd (1961) showed that treatment at green tip with lindane 0.07 per cent to 0.1 per cent gave good control of woolly aphid, if it were applied thoroughly and included drenching of the soil at the base of the trunk.

Lindane 0.06 per cent-in-oil 3 per cent is recommended at the green tip stage. Later in the growing season, systemic insecticides such as demeton-S-methyl 0.03 per cent, or dimethoate 0.03 per cent, or pirimicarb 0.03 per cent, or vamidothion 0.05 per cent should be applied when infestation build-up is first noticed, usually after mid-November. Vamidothion, which is regarded as the most effective of the systemic insecticides for this purpose, may cause spotting of fruit, mottling of leaves and blistering of bark on Delicious apples if applied in November–December in the Orange district. Starkrimson apple trees are especially susceptible to bark damage by vamidothion. After harvest, lindane 0.06 per cent is recommended for heavily infested trees.

Nursery trees with gross root infestation have been cleaned by immersing the roots in a solution of organophosphorus (OP) material before planting out. For young apple trees before planting, dipping the whole tree in an OP insecticide, such as dimethoate 0.03 per cent, is effective; the treatment of the above-ground part is of value also against San José scale.

Spiraea aphid *Aphis citricola*

This aphid has been found on the terminal foliage of apples mainly in summer–autumn. Infestations have not been damaging, and the aphids have been attacked by lacewing larvae and the ladybird, *Platyomus lividigaster*.

San José scale *Comstockaspis perniciosus*

Importance and Distribution This scale, named in 1881, first appeared in San José, California in about 1870 after the importation of plants from China. It now has an almost world-wide distribution. It is not an important pest in Tasmania, although it is occasionally reported there. The oystershell scale, *Quadraspidiotus ostraeformis* (Curtis), and the pear scale, *Q. pyri* (Lichtenstein), are related to it and similar in appearance (Brookes and Hudson, 1968). They occur in Australia, but they are not nearly as harmful as the San José scale.

While this scale is noted for its destructiveness, it also has special importance as infested fruit are subject to strict quarantine when entering European countries. Consignments of fruit which have even an occasional scale, dead or alive, are refused entry.

Conditions for Infestation San José scale develops best in a relatively warm dry climate. Even so, in New South Wales it is widely distributed in coastal as well as inland districts, and is capable of developing in a wide range of conditions. Heavy infestations are seen in even the coldest apple districts of the State. Dust in the orchards may encourage this scale as it does some others. Modern spray chemicals used for codling moth and oriental fruit moth may result in increased populations of some pests but this is not a major factor with San José scale. For almost a century, San José scale has been notorious for its occasional great upsurges in infestation in many countries, a phenomenon which has not been explained satisfactorily. Similar gross infestations have been seen on self-sown, home-garden and ornamental street trees which have never been subject to spray treatments. In mixed orchard plantings of peaches and pears, and sometimes plums, more serious infestations of San José scale develop than on apples, although apples receive much more spraying than the others. Definite evidence of the stimulating effect of modern pesticides on San José scale in New South Wales is lacking.

Plants attacked San José scale may develop on many orchard trees, on ornamentals, and on many hedge plants such as japonica, hawthorn, osage orange and tree lucerne. Citrus is often included in lists of hosts, but this is considered to be unjustified where quarantine measures are likely to be invoked. Apart from occasional records of infestation of *Poncirus trifoliata*, which is used only as a root stock, commercial varieties of citrus cannot be regarded as hosts (Quayle, 1938). There is no record of San José scale on citrus in New South Wales, even from citrus growing beside heavily infested deciduous trees.

Description and Life History The adult female scale cover is roughly circular in outline and 2 millimetres in diameter, while the male is oval and smaller. The colour varies from pale to dark grey or almost black. A heavy bark infestation appears as a scurfy grey mass of overlapping scales, and the yellow bodies of the insects themselves will usually become visible in the mass if the scurf is scraped. Active six-legged yellow oval larvae are produced by the female and they settle on the bark, usually close to the parent. Each inserts its long thread-like rostralis or feeding tube, and injects a substance toxic to plant cells in the process.

The female moults twice; the male has a more complicated development involving five moults. The adult male is winged and yellow. After the young female scale settles, it does not move. The full-grown body of the female, under its round cover, is rather kidney-shaped, swollen-looking and bright yellow. The female can produce up to 400 larvae and, in summer, the females amongst them can mature and give birth to new young in six weeks. The increase in population can be extremely rapid. In the winter, scales of all ages may be found in the warmer districts. In colder areas only second-stage young, often referred to as 'black caps', are likely to be found. Larvae of the new season's first brood may be seen in the spring when young fruit is setting. Very high populations may build up by late summer, and the small yellow larvae become very evident at harvest when they fall on the hands and clothing of the pickers.

Injury The effects of San José scale attack may be seen on all above-ground parts of the tree, but leaf infestation happens only when the population reaches plague proportions and the insects on the leaves are then mostly males. Trunks, limbs, and twigs are all damaged. Large limbs may be killed and often whole sections of the tree framework are seriously weakened; this type of unequal infestation is common, so the appearance of dead limbs in a tree suggests San José scale. Gum exudation is a common result of scale attack on stone fruits, but gum is not produced by apples even when grossly infested. Often infestation is not suspected until gross symptoms of damage are evident. It is well named *perniciosus*. In autumn, under favourable conditions, huge numbers of larvae can move out to the lateral and spur growth. At pruning time the grower is surprised to find

San José scale
Comstockaspis perniciosus

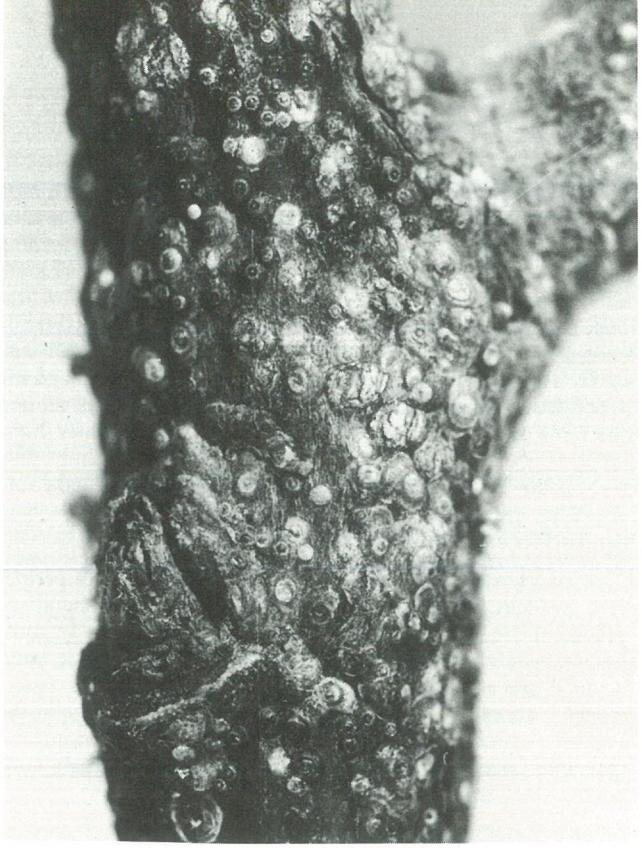
1 First-stage scale or 'crawler'; **2** second-stage female; **3** adult female; **4** scale cover of male; **5** scale cover of female; all enlarged thirty-five times. **6** Scales on twigs and leaves; actual size.

that much of the fruiting wood for the next season has been killed.

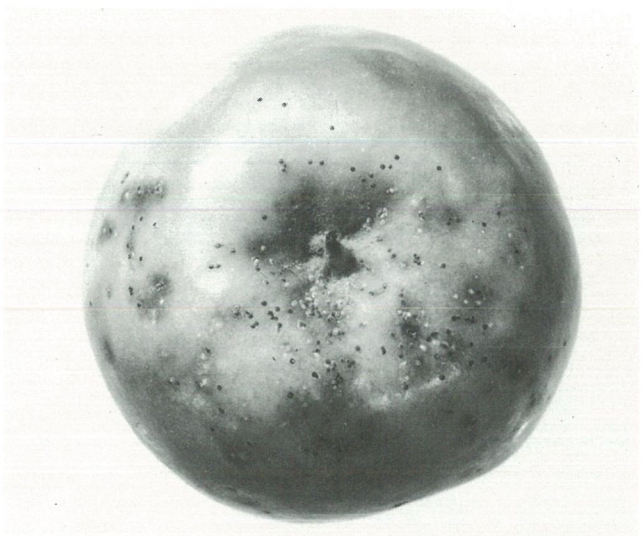
Infestation of the fruit of apples and pears is common, and each scale produces a red spot. This is not a characteristic confined to San José scale, as red spots may result from the presence of other scale species such as oystershell, mauve pittosporum and California red scales. Similar small red spots on the lateral wood of peaches and apricots are not the result of injury, but are natural markings associated with lenticels.

Dispersal The main means of introducing San José scale to orchards is undoubtedly through infested nursery stock. Young trees may have scales on bud or scion wood taken from infested trees. Great care should be taken to see that propagation wood comes only from clean trees. Wood for budding can have scales hidden under the buds.

Most dispersal within the orchard is at the larval stage. The larvae are very active and may be blown by the wind or carried by birds, insects or man. They can be moved about on picking



San José scale – dense infestation on apple twig.



San José scale – heavily infested apple.

bags, field boxes and ladders. However, the larvae can only live for a day or two away from the host. There is good evidence that birds may carry the larvae over long distances; seedling fruit trees growing at some distance from orchards have become heavily infested.

Control measures

NATURAL San José scale is attacked by ladybirds, lacewing larvae, caterpillars of the moth *Batrachedra* sp., and by small wasp parasites, but these have little economic effect.

APPLIED Thorough spraying right down to ground level is essential when treating for San José scale as it may infest all aerial parts of the tree. The trunk and butt will be infested and will provide effective shelter in bark crevices. Generally, automatic drive-past sprayers fail to give sufficient coverage of the trunks. There are many examples where poor control has resulted from their use.

Lime-sulphur and oil sprays in winter have traditionally been favoured for treating San José scale. One of the earliest indications of insecticide resistance was the difficulty in controlling this scale with lime-sulphur, recorded by Melander (1914). This finding has never been confirmed in New South Wales, so lime-sulphur is still recommended for green tip spraying.

For a light infestation a single spray while the trees are dormant or semi-dormant is usually sufficient.

When San José scale is well established, especially on mature and rough-barked trees, two sprays are necessary – the first in winter and the second in spring. Two full-strength oil sprays should not be used.

Winter oil spraying using superior dormant oil 3 per cent is the most common method of control. This should be followed when infestation is heavy with lime-sulphur 1 per cent (polysulphides) plus superior dormant oil 1 per cent at the green tip stage. Ethion 0.04 per cent-in-oil 2 per cent is recommended for winter to green tip spraying.

If spraying is necessary after harvest, carbaryl 0.1 per cent plus petroleum oil 1 per cent or ethion 0.06 per cent-in-oil 1 per cent is recommended. Methidathion 0.05 per cent used in the growing season is also an effective treatment.

Dormant young trees can be treated, after their removal from the nursery rows and before planting, by dipping them (excluding the roots) in a suitable oil emulsion, such as superior dormant oil 3 per cent, or in carbaryl 0.1 per cent plus petroleum oil 1 per cent. After dipping, drain the trees in the shade, tops downwards. Such treatment can delay the appearance of San José scale in the orchard for years.

Careful inspection of trees from which propagation wood is to be taken is important. Recently-applied oil sprays may have a deleterious effect on propagation wood, so its disinfestation by dipping in oil would not be suitable.

It is important that the many plants that may be hosts to San José scale and are commonly used as windbreaks or ornamentals are not overlooked as sources of re-infestation.

Mauve pittosporum scale *Parlatoria pittospori*

This species is of no direct importance as a pest in apples in New South Wales, but is described here as it appears occasionally on apple fruits and may be confused with San José scale, which is totally unacceptable on export fruit. It was first described in 1890 infesting *Pittosporum* in Australia, and has since been recorded in South Africa, New Zealand and California. In Australia, it is a widely-distributed species on many native and introduced plants. Although occasional individual scales are found on apple fruits, it has never been known to cause any harm. In New Zealand, Timlin (1964) studied this scale where it infested shelterbelts of *Pinus radiata*. It was quite abundant on the pines which could have provided a source of wind-borne

infestation to the apples, but it was rarely seen on the apple trees except occasionally on the fruits. On some apples scale development produced red spots. In New South Wales, infestations by this scale have been extremely light.

The scales themselves are an inconspicuous greyish brown. The females are about 3 millimetres long and somewhat pear-shaped or oval. The scale body under the cover and the eggs are light purple. The males are slightly smaller than the females and more elongated. There is only one generation per year and, in New Zealand, crawlers begin to appear in October and continue to do so until after the harvest.

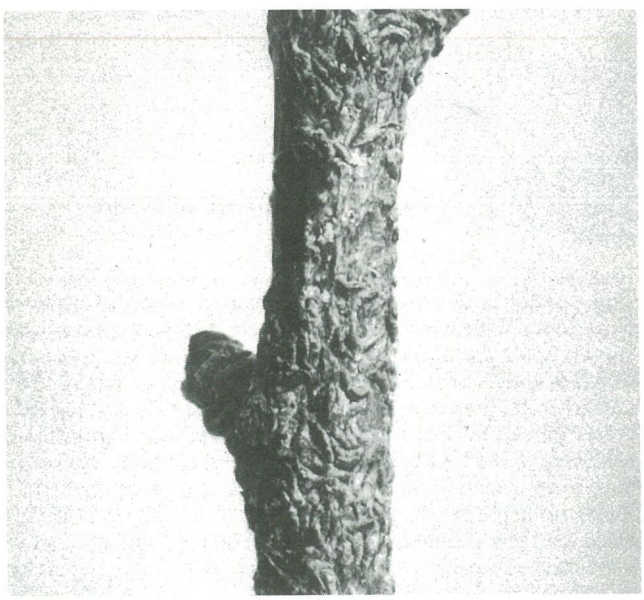
Apple mussel scale *Lepidosaphes ulmi*

This scale is an unimportant pest of apples in New South Wales. It is usually confined to old neglected trees and those growing in home gardens in the colder apple districts. It has a wide host range amongst deciduous fruits, but is found most commonly on apples.

The adult is about 3 millimetres long, somewhat mussel-shaped, tapering and often curved. It is usually light grey-brown to dark brown and may be shiny.

During winter the female covers are packed with masses of white eggs. These hatch in late spring, and the cream six-legged crawlers wander for a few days before settling on the bark of the older wood, or on the laterals and spurs. Usually the crawlers settle near old scales and the infested area becomes thickly encrusted with a mass of old and new scales. Heavy infestations may kill the twigs or even larger wood. Development from crawler to the next brood requires about three months. Some crawlers of the second generation infest the fruit.

Control measures Control of apple mussel scale is achieved by winter application of oil sprays, but in heavy infestations a further treatment would be needed in late spring as recommended for San José scale on page 109.

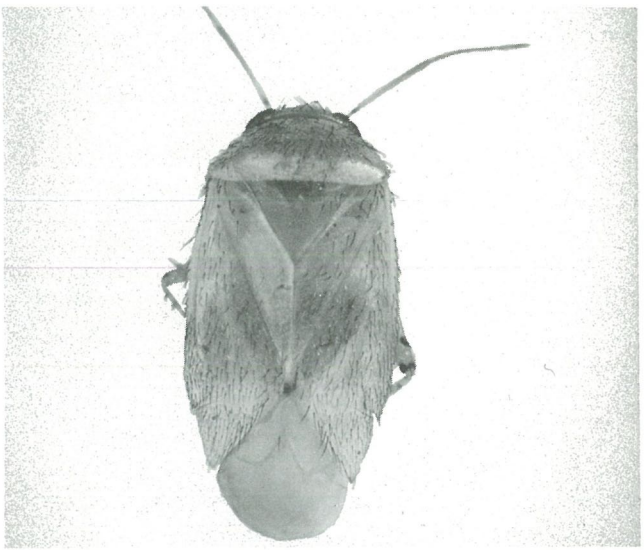


Apple mussel scale – heavy infestation on twig.

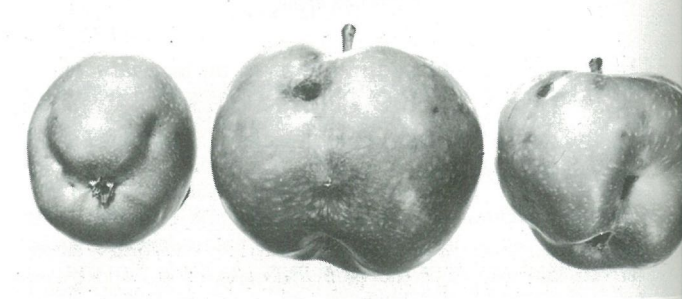
Apple dimpling bug *Campylomma livida*

In some districts, especially in the Central Tablelands, Delicious and Granny Smith apples suffer a deformity – they are lumpy and ill-formed at maturity and have one or more depressions or dimples on the surface. This condition is due to the feeding punctures of a very small mirid bug at blossom time (Lloyd, 1969). The full-grown bugs are insects about 2.5 millimetres long, pale green, squat and very active. They run or fly readily when disturbed. The wingless nymphs are also pale green and active. The adults feed by puncturing the flower organs and the young fruitlets, producing small raised scabbed areas around which the tissues fail to grow normally, and resulting later in the lumpy appearance of the fruit. Apple dimpling bugs can be seen easily if the blossom clusters are jarred sharply over a dark surface. They are always more numerous on trees near the headland than further into the orchard.

Control measures Where apple dimpling bugs are a permanent problem, Delicious and Granny Smith apples should be sprayed at the late pink stage with DDT 0.1 per cent. In some seasons re-infestation may occur at full bloom or a little later, in which case a second spray should be applied. To avoid danger to bees it should be applied early in the morning or late in the evening – times when the bees are not actively working the blossoms. Care must be taken not to spray under frosty conditions when spray injury can result.



Apple dimpling bug. (Length about 2.5 mm)



Deformed mature apples which were damaged when very young by apple dimpling bug.

Apple leafhopper *Typhlocyba froggatti*

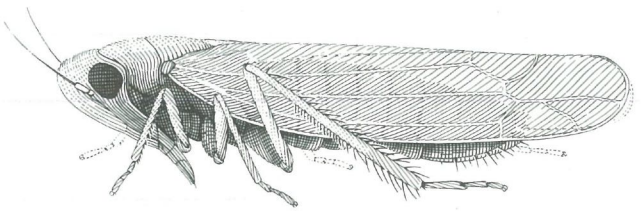
This insect, also known as the 'apple jassid' or 'canary fly', is a pest in most apple districts in the State and has been recorded injuring prunes. Before the introduction of DDT for codling moth control, it was a rather serious pest but, nowadays it is of only minor significance on cropping trees with codling moth spray programmes.

Both adults and nymphs suck sap, mostly on the undersides of leaves. The feeding produces a mottled grey appearance of the foliage and, in heavy infestations, the leaves turn yellow and fall prematurely. More serious damage is caused by feeding on the fruit due to the unsightly brown spots of excrement that are difficult to remove.

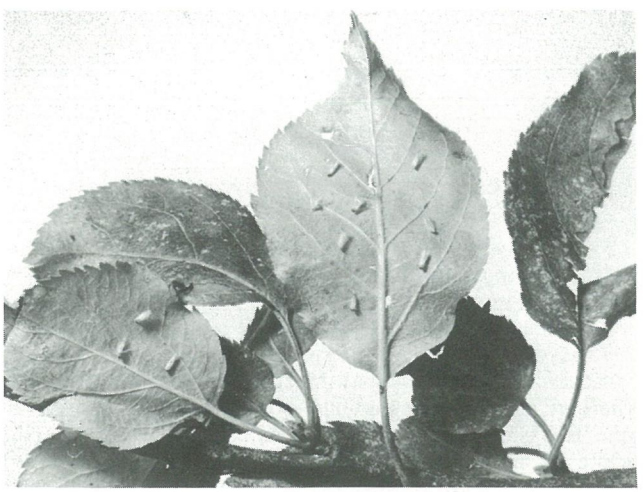
The adult leafhopper is narrow and torpedo-shaped, yellowish green with red eyes, and about 4 millimetres long. It has two pairs of wings, and the hind legs are adapted for jumping. The nymphs are like the adults but without wings. There are two main overlapping generations in the year. The minute elongate eggs are laid singly in the leaves and bark of young wood, and small elongate swellings show their presence.

The eggs overwinter and start to hatch in late September; the young continue to appear until early November. Adults are most numerous at about the end of October. The females of this generation oviposit in the petioles and main veins of leaves. These eggs hatch from early December to mid-February and adults are present in the orchard from late December to the end of March. These second-brood adults lay their eggs in the bark where most of them overwinter. A few hatch as a small third generation in autumn.

Control measures The pest is normally controlled by the codling moth spray programme using azinphos-methyl 0.05 per cent.



Apple leafhopper. (Length about 4 mm)



Apple foliage infested by apple leafhopper.

Wingless grasshopper *Phaulacridium vittatum*

Importance and Distribution The wingless grasshopper is widely distributed in pastures in eastern and southern Australia, including Tasmania, and in the south-western districts of Western Australia (Key, 1939). In New South Wales it is found on the Southern and Central Tablelands and Slopes, and on the Northern Tablelands. Very severe and widespread infestations occurred in New South Wales and Victoria during the 1964–65, 1976–77 and 1977–78 seasons. These resulted from the high survival of young hoppers during the dry springs, particularly where intensive grazing has occurred.

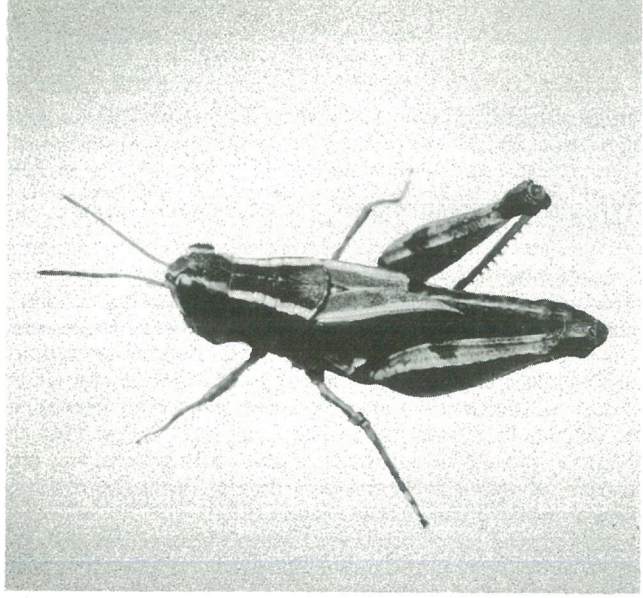
Many broad-leafed plants are favoured hosts of this pest, and crops and gardens are frequently damaged. Pastures may also be seriously damaged during dry seasons. It has been recorded as a pest of cultivated crops and plantations in Queensland, New South Wales, Victoria and Tasmania.

Conditions for Infestation Its distribution is related to rainfall as it is usually found from the coast westwards as far as the 500-millimetre rainfall isohyet, and sometimes further inland in moist habitats. The introduction of improved pastures is closely related to the increase in importance of this grasshopper as a pest in New South Wales. The combination of heavy grazing and the introduction of subterranean clover helps to provide open low pastures which favour the survival of first-instar nymphs in spring. They feed on prostrate and rosette-forming plants but many are unable to find these where grasses form the dominant plant cover, and so fail to survive. Older hoppers and adults have a much broader host range and are able to survive on the grass component of pastures. In moist summers no trouble need be anticipated in orchards, as these pests move into orchards only when their natural food supply of herbage and broad-leafed plants dries out. This dispersal may take place at any time between December and February or, in unusually dry seasons such as 1977, as early as October.

Plants attacked The wingless grasshopper has a very extensive host range with most fruit trees, vegetables, garden plants and cruciferous forage crops likely to be attacked. Feeding has also been observed on native trees, vines, and sometimes bracken fern. Foliage and fruit may be fed upon avidly. In commercial orchards young trees are the most likely to be affected.

Description and Life History Despite the name, wingless grasshopper is not entirely wingless as a very short scale-like wing may be seen on each side of the mid-dorsal line. The wings are thin and papery, rather than thick and fleshy like the wing buds of the hoppers of other species. Sometimes fully-winged individuals may be found amongst the more usual short-winged ones; up to 10 per cent or 15 per cent of a local population may have functional wings. The hindwings of the fully-winged form are rather smoky-coloured. Clark (1967) observed that the wingless form was by far the most abundant in pastures, but that the winged form dominated in gardens, strips along forest margins and where shrubs were growing.

Females are 12 to 18 millimetres long, but the males are 12 millimetres long or less. They are brown or grey and frequently paler on the top than on the sides. Green forms are never found.



Wingless grasshopper. (Length 12 to 18 mm)

Foliage (plum) damaged by wingless grasshopper.

The shanks of the hind legs are usually red. In dense populations, dark or almost black forms may be found.

Wingless grasshoppers overwinter in the egg stage. The active stages will be found from about late spring until mid-autumn and, although a diapause occurs in the egg stage, this is usually broken by July. There is a single generation each year. Hatching begins from October to December and the delicate 'hatchling', which is at first unpigmented, shortly becomes black. There are five nymphal instars of an average total duration of six to seven weeks. Adults first appear between November and February and a large proportion of both males and females survives until April; most die before May, although a few will survive until the following spring in sheltered situations. In the south, females lay their first egg pods of about fifteen eggs between ten and fourteen days after the final moult, and thereafter as many as nine more pods may be laid at various intervals until death.

Injury Infestation by wingless grasshoppers usually begins in the lower branches of trees. The leaves and fruit are chewed and defoliation may result from severe attacks.

Dispersal In dry seasons, from early to mid-summer onwards swarms of wingless grasshoppers (wingless and winged forms) may migrate into orchards from their breeding areas when the seasonal drying-off of annual plants occurs.

Control measures

NATURAL Natural enemies do not appear to play a significant part in the control of these pests. Investigations in the 1970s by the New South Wales Department of Agriculture (unpublished) revealed several parasites. These include the nemestrinid fly *Trichopsidea ostracea* Westwood, a mermithid nematode, a sarcophagid fly, *Blaesoxipha pachytyli* (Skuse), and the wasp parasite *Scelio improcerus* Dodd.

APPLIED Spraying infested herbage around trees and infested trees, or trees and herbage around them likely to be infested, with fenitrothion 0.03 per cent, or dimethoate 0.03 per cent or fenthion 0.04 per cent is recommended. A strip of infested grassland at least 10 metres wide around the margins of orchards should also be sprayed with these insecticides, particularly if the grasshoppers have not yet invaded the block in any numbers. The trees should be kept under observation and sprayed again when any re-infestation of the area is seen.

Apple eaten by wingless grasshopper. P.R.I., Dept of Ag. Vic.

ARACHNIDA ACARINA

Two-spotted mite *Tetranychus urticae*

Importance and Distribution Several species of *Tetranychus* occur on various plants in New South Wales, but surveys have shown that *T. urticae* is invariably the one involved in infestation of deciduous orchards (Gibson, 1966). Two-spotted mite, formerly called 'red spider', is a serious pest of fruit trees in many countries. It is very important in Australia, except in Tasmania where its position of importance is taken by the European red mite. It was of little importance as an orchard pest in Australia before the introduction of DDT to control codling moth and oriental fruit moth. Infestations used to be rare and of short duration when mites migrated in summer to the trees from

ground flora in the orchard, or from crops such as beans grown between the trees when the crop dried off. When DDT killed the natural enemies of the mites – ladybirds, lacewing flies, predacious thrips and predacious mites – on the ground flora, a great increase in mite populations resulted. The mites appear to have become adapted to a permanent life on the orchard trees. In orchards where natural enemies have been killed by insecticides and mite populations have increased, stopping the use of such insecticides is usually followed in a season or two, but maybe longer in some areas, by a reduction in the mite population attributable to the return of the natural enemies.

Thus damaging infestations of two-spotted mite in pome fruit orchards are closely associated with the use of modern insecticides for codling moth control. Until the moth can be controlled by means which are less destructive to the mite's predators, the problem will continue.

Conditions for Infestation Apart from pest control programmes, the conditions most favourable to two-spotted mites are hot dry summers. Continuous periods of rainy weather strongly depress mite populations, as do heavy rain storms. In hot dry weather the effect of even a few mites on the trees can be severe. This is especially true of pear trees.

Plants attacked There are few plants that cannot support colonies of two-spotted mites under suitable conditions. Apple (especially Delicious), pear, peach, plum and prune trees are most frequently infested seriously. Plums and prunes grown alone are not particularly subject to infestation, and apricots and almonds are not commonly troubled. Citrus trees only carry populations of mites when they become grossly infested from nearby sources, and when they receive excessive spray drift from other trees nearby.

Description and Life History The adults are small greenish yellow eight-legged mites up to 0.5 millimetre long. The females are rather pear-shaped. They are capable of active movement, and they spin fine webbing over the surface on which they are feeding. The males are smaller and narrower. Both females and males have a dark spot on each side of the body. The eggs are spherical, colourless when fresh, but changing later to yellow.

Two-spotted mite – adult female and eggs. (Length of adult female up to 0.5 mm)

They are laid on the leaf surface in the tangled webbing at the rate of up to seven per day, and up to 70 will be laid in the lifetime of one female. The larvae which hatch from the eggs have six legs, but later stages, known as 'nymphs', have eight legs. The period from egg to adult spans only about seven to eleven days in summer. Breeding goes on throughout the year if food is available and the temperature is not too low.

Feeding on deciduous trees ceases in autumn, and the overwintering non-feeding forms appear. These are orange-red and without the dark spots, and they begin to appear in early February on heavily infested trees. They make their way down to the crotch, or to the base of the trunk, and congregate under the shelter of bark and accumulated debris where they produce webbing, often in great profusion. Some mites assemble higher up the trees in cracks on the lower sides of branch junctions, and they may also be found in stem cavities and in bird pecks in apples still hanging. The overwintering forms become active early in spring and usually move down to weeds and herbage around the butts. They begin to feed and change colour to the green form with dark spots on the body. If early spring is warm and bud-burst is early, many of the overwintering two-spotted mites may move directly to the spurs and laterals, and feed on the developing blossoms and foliage. This type of infestation is usually short-lived, but it can cause serious damage. As the trees foliate and ground cover becomes abundant, the mites soon disappear from the trees.

On the ground, the mites feed on many plants, preferring legumes such as sub-clover and vetches, and then broad-leafed weeds. They will feed on grass only if other suitable plants are not available. When the ground plants dry off or are turned in by cultivation, the mites move into the trees. Infestation first becomes evident in the lower central parts of the trees, and the mites gradually spread upwards. On apple trees they feed mainly on the lower surfaces of leaves. On peach trees feeding on the upper surfaces is common. They pierce the leaf cells and suck out the sap.

Some mites in protected places, and with a satisfactory food supply, do not change colour in winter. They continue normal development but at a slow rate. The red overwintering forms also can be induced to feed and resume the normal activity and appearance of the summer forms if provided with food and a warmer temperature. Females have been held at a low temperature experimentally for many months. Later, when under more favourable conditions, they resumed the activity and colour of the summer form and laid viable eggs.

Bengston (1965a) concluded from his studies at Stanthorpe, Queensland, that the winter form is not a true diapause but a state of quiescence, and that only a small proportion of the affected individuals overwintered successfully in that district.

Injury The first sign of two-spotted mite injury is a light speckling or peppering of the leaves, which later becomes generally grey, and ultimately bronze. There is also some up-rolling of the leaf margins. This may be followed by leaf-fall which can expose the fruits and limbs to sunburn. In addition, fruit may be undersized and red varieties may fail to colour evenly and fully. More importantly, the amount of autumn foliage carried may influence the amount of root growth; early defoliation year after year can have an important cumulative effect on tree development.

The presence of overwintering mites on export fruit does not usually result in quarantine restrictions, but apples for the United Kingdom must not have more than a specified maximum number of such mites.

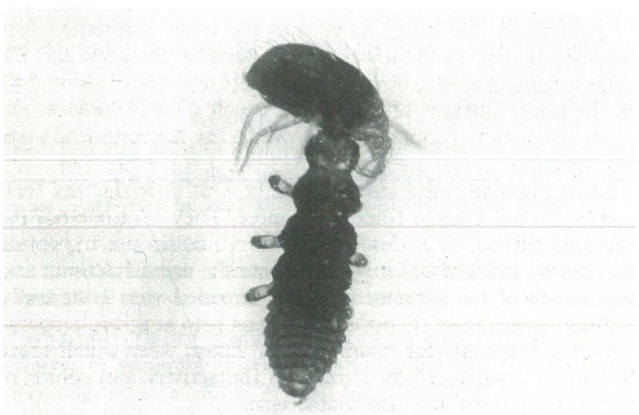
Dispersal Mites move into the trees from ground flora as described above. On maturity, young females move upwards in the tree before they lay eggs, but, after feeding and egg-laying have started, they move very little. Newly-infested leaves have mature females and eggs. Leaves which have been infested for longer have mites of all ages.

Movement from tree to tree depends mainly on the transfer of mites or eggs enmeshed in webbing, on birds and visiting insects, wind-blown leaves, and humans. Direct transfer of wind-borne mites appears to be less important, although Boyle (1957), in Hawaii, showed some movement of mites by wind. Tests in infested orchards in the Murrumbidgee Irrigation Area, using sticky targets, found very little wind-borne movement (Anon, 1966).

Introduction of two-spotted mites to the orchard on nursery trees is of little importance as such trees are usually free from this pest. Two-spotted mite is of little importance as a pest of apples until the trees are mature enough to require spray programmes for the control of other pests.

Control measures

NATURAL Two-spotted mites are held in check by many predators under natural conditions. The tiny black ladybirds *Stethorus* spp. and their larvae are extremely important as predators. When mites are numerous at the end of the season and spray programmes cease these ladybirds can bring about a spectacular drop in infestation. There are many other predators. The insecticides used for codling moth control are generally harmful to native natural enemies of two-spotted mite.



Ladybird larva feeding on two-spotted mite.

The introduced predatory mite, *Typhlodromus occidentalis*, which is resistant to certain insecticides, particularly azinphos-methyl, is proving to be valuable in controlling two-spotted mite in New South Wales orchards. It was introduced to Australia from North America. Since its introduction trials by both entomologists and growers have demonstrated its effectiveness as a predator provided that sprays which may kill it (certain insecticides and fungicides) are not used. This predatory mite does not eradicate two-spotted mite from the orchard but prevents it from increasing to a level of intensity which will damage trees. The control process is dynamic and a delicate balance between the two has to be maintained.

APPLIED Thorough and timely application of an efficient miticide can provide good control of two-spotted mite for up to five or six weeks. Most instances of poor control have resulted from inadequate application (Johnson *et al*, 1972). For mite control, it is essential to cover all the foliage surfaces, especially the lower surfaces. Drive-past sprayers often cover foliage inadequately for mite control. Even with efficient spraying it may be necessary to repeat a spray within ten days to reduce heavy infestations to low levels, but it is more usually done three to six weeks later.

Lloyd (1962) traced the history of the use of different materials for the control of two-spotted mite since it became a major pest in apple orchards. Parathion, and later maldison, extensively used for several years, had the serious disadvantage of requiring repeated applications to achieve reasonable control. The benzene sulphonate group, including fenson, chlorbenside and chlorfenson, were used commercially in a limited way. As ovicides only, they were insufficiently effective against a pest producing eggs continuously through the season. Dicofol, methyl demeton and tetradifon were found effective in 1957 about the same time as organophosphorus materials with longer residual action, such as carbophenothion and azinphos, were introduced for codling moth control. These also gave good control of two-spotted mite, carbophenothion being particularly good. However, mite resistance or tolerance appeared and, by the 1962–63 season, azinphos could no longer be recommended for two-spotted mite in the Orange district. Dicofol and tetradifon were largely relied upon for mite control from then until about the mid-1970s.

Spraying with azocyclotin 0.05 per cent, or bromopropylate 0.075 per cent, or cyhexatin 0.02 per cent, or fenbutatin oxide 0.02 per cent, or propargite 0.06 per cent is now recommended for control.

The problem of rapidly developing resistance to new materials is a difficult one. Changing from one miticide to another has not provided the answer. Any procedure that reduces the population of mites on the trees or on the ground cover should be used. Experimental work by Lloyd at Orange (Anon, 1966) sought to make use of the characteristics that non-feeding forms overwinter on the trees and re-infestation by wind has little importance. It was aimed to have the trees free from mites in the spring by cleaning out crotch debris and spraying at the end of winter with an efficient miticide. The trees were then banded with 'tree tanglefoot' and the ground kept clear from weeds. None of these procedures kept the trees free from mites for the whole season, but it was possible to delay spraying by up to 45 days in summer.

Bryobia mite *Bryobia rubrioculus*

Importance and Distribution Bryobia mite, formerly called 'red mite', is one of the most well-known pests of apples and other deciduous fruit trees. It is world-wide in its distribution. Until recently, it was mistakenly named *Bryobia praetiosa*, which was thought to attack fruit trees as well as herbage plants, especially clover. The different forms have now been recognized as distinct species – the one on herbage being *B. cristata* (Dugès), and the one on trees being *B. rubrioculus*.

Bryobia mite is generally not an important pest of apples. It is more damaging to almonds, prunes and sometimes pears. It is an unexplained fact that it is far less abundant than it used to be. As two-spotted mite has become more numerous, so bryobia mite has decreased.

Conditions for Infestation Hot dry conditions suit bryobia mite, and wet cold weather destroys large numbers. They have obvious difficulty in moving over wet surfaces. Tree nutrition is

an important factor, and it has been suggested that the increased use of nitrogenous fertilizers in orchards has made the trees less favourable to bryobia mite and more suitable to two-spotted mite. It is certainly true that old neglected trees with a low plane of nutrition will harbour many bryobia mites under almost any conditions.

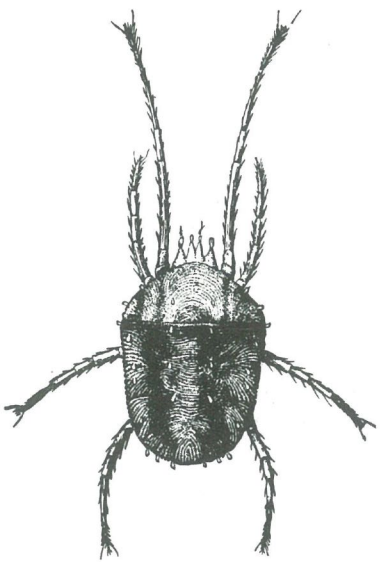
Plants attacked Almonds, prunes, plums, pears, apples and apricots are fairly commonly infested, as also is the ornamental, hawthorn. Amongst apple varieties, Delicious is much more susceptible than Granny Smith.

Description and Life History Bryobia mites overwinter as eggs that are laid in the autumn on trees or on stones. The eggs are smooth, spherical and dark red with a dull shine. They are laid in masses and, when numerous, form a red covering over the bark. Favoured places for egg-laying are at the junctions of limbs, on fruit spurs, on leaf and fruit scars, in fissures in the bark, or on any similar rough surface. After the eggs have hatched, the white shells, together with cast skins, remain on the bark for some time as a white layer.

Spring hatching of overwintering eggs begins in about early September, but the date is influenced by the host variety. The newly-hatched mites have six legs and are bright red, but they turn green as they begin to feed. The eight-legged nymph is produced after a few days, and there is a second nymphal stage before the adult. Full development takes about a month, but varies with temperature.

The adults are all females. They are about 0.6 millimetre long and vary in colour from reddish brown to greenish grey with orange legs. The general shape is oval and the body is somewhat flattened on top with a flanged edge; in side view, it is rather box-like. The first pair of legs is much longer than the others and is carried forwards in front of the head.

Adults bred from overwintering eggs lay eggs which are similar to those from which they hatched, but place them singly on the lower surfaces of the leaves, usually close to veins or around the bases of leaf stalks. A female may lay up to 30 eggs, but the number is lower later in the season. The incubation period varies from about three weeks to a month at daily mean temperatures of about 16°C, but is much shorter at higher temperatures (Kremer, 1956). The mites feed mostly at night on the upper surfaces of leaves, returning to shelter during the day. They do not make webbing.



Bryobia mite. (Body length about 0.6 mm)

Injury Bryobia mites pierce the epidermal cells with their sharp mouthparts and suck out the contents. This injury shows up on the upper surfaces of young leaves as whitish grey spots which spread to give the leaves a stippled appearance. The greenish grey stippling is retained by the leaves until they fall. The bronzing, typical of two-spotted mite or European red mite, is not produced. Very young leaves attacked in the spring by bryobia mite become markedly discoloured and fail to grow. The affected upper surface is reduced in photosynthetic capacity, which results in a weakening of the trees. Very severe damage can be caused by a relatively small number of mites (Lloyd, 1959); individually they can cause more harm than the two-spotted mites.

Dispersal The initial introduction of bryobia mite to an orchard is generally on nursery trees, which have themselves become infested from eggs on propagating wood.

Within the orchard, movement of mites from tree to tree is by visiting birds and insects, and on the clothing of orchard workers. However, movement by these agencies is restricted as the mites seek shelter away from the leaves for most of the day. Bryobia mites of all ages are active crawlers. If they drop to the ground freely or on prunings, they will usually return to the tree. It has been shown that, when infested prunings were dropped in the early winter and the tree was later thoroughly sprayed, mites hatching from eggs on the prunings would climb the tree in spring.

Control measures

NATURAL Predatory ladybirds – including common spotted ladybird, *Harmonia conformis*, and *Stethorus* sp. – have been seen attacking bryobia mites, and so have lacewing larvae.

APPLIED Winter spraying with superior dormant oil 3 per cent, or a combination spray of lime-sulphur 1 per cent with superior dormant oil 1 per cent applied at green tip, will give excellent results against bryobia mite eggs if done thoroughly. Prunings that will carry eggs must be picked up and destroyed.

It may be necessary to spray in spring or early summer if winter spraying has been missed, or if the season is especially favourable to the mite. Spray schedules including organophosphorus compounds for codling moth control will usually take care of bryobia mite but, if it becomes necessary, dicofol 0.04 per cent will be found to be effective.

European red mite *Panonychus ulmi*

Importance and Distribution European red mite was first recorded in New South Wales in 1954 at Orange and subsequently on the Northern, Central and Southern Tablelands. Infestations were light, causing no serious damage. Recently, it has increased rapidly at Batlow in the Southern Tablelands and is now established as a serious pest in many orchards in the district (Bower, 1977). It was first seen in Queensland at Stanthorpe in 1957 where Bengston (1965b) considered it as second only in importance to two-spotted mite. It is the dominant mite pest of apples in Tasmania. European red mite is one of the more important pests of deciduous fruits in Europe and North America.

Conditions for Infestation The persistence of this mite depends on the successful production of winter eggs, and on spring conditions that induce the breaking of the diapause and the hatching of these eggs. Winter eggs may be produced in January if the trees have suffered heavy mite damage. If these eggs are subjected to hot weather, they will die, but if they are deposited in a cool summer, they will hatch after going through the period of winter cold. If the mites are not overcrowded in the summer, they will lay winter eggs in March which will usually be healthy.

Overwintering eggs, if normal, hatch at green tip stage in mid-September in Stanthorpe (Bengston, 1965b) and the females developed from them lay summer eggs.

Plants attacked European red mite occurs on many fruit trees, shade trees and shrubs, but in New South Wales has been seen only on apples and plums. In Tasmania, the apple varieties Delicious, Sturmer Pippin and Crofton are much more subject to severe infestation than Jonathan, Cleopatra or Worcester (Miller, 1953).

Description and Life History European red mites overwinter as onion-shaped red eggs – the eggs are spherical, but somewhat flattened, with a distinct style or stalk at the apex. They are laid in autumn on twigs and small branches, and hatch in the spring. The six-legged larvae crawl to the young unfolding leaves and start to feed. There are two eight-legged nymphal stages before the adult stage. There are males as well as females, the males being smaller and paler. The females are brownish red, oval and about 0.3 millimetre long. They have four rows of long stiff curved spines, each arising from a white tubercle, down the back. The life cycle takes one or two weeks, and females can live for nearly three weeks. They each lay up to 20 summer eggs which develop quickly. Feeding and egg-laying are always on the undersurfaces of leaves. No webbing is produced.

Injury Initially the damage shows up as a speckling of the leaves. As the population increases the foliage becomes pale and, in heavy infestations, bronze. Leaves may fall, and the fruit may be small and of poor quality. Fruit buds may be prevented from forming. Injury is always worse when trees suffer water stress.

Dispersal Spread from place to place is mostly on nursery trees, and on scion wood carrying overwintering eggs. Within the orchard the mites may be windborne or carried on infested leaves. They may be carried also by man, birds or insects.

Winter eggs are sometimes laid on late-hanging fruit, especially in calyx and stem cavities, which may act as a source for dissemination.

Control measures If treatment is necessary, dormant spraying with superior dormant oil 3 per cent, or 2 per cent at green tip, is recommended. Later in the growing season, spraying with bromopropylate 0.06 per cent or cyhexatin 0.02 per cent is recommended. Further applications may be necessary at intervals of four to five weeks. Thorough wetting of the whole tree is necessary for optimum control.

Pear pests

Most of the commercial pear varieties grow best in the cooler parts of New South Wales. Williams Bon Chretien (Williams), an important fresh fruit and canning variety, also grows well in warmer parts of the State, such as the Murrumbidgee Irrigation Area. Pear production in New South Wales is dominated by Packham's Triumph, a locally-originated variety, and Williams. Other varieties include Beurre Bosc, Winter Cole and Josephine.

The following is an approximate phenological table.

Green tip	–	late August to early September
Spur burst	–	early to mid-September
White stage	–	mid- to late September
Full bloom	–	late September to early October
Petal-fall	–	mid-October

Harvesting of Williams in the 'early' districts begins in January, and continues in the tablelands districts well into February. The other main varieties follow on, and all harvesting is usually completed by early April.

Pears are subject to two important fungus diseases, scab and fleck, which require a carefully-timed programme of protective fungicidal sprays, especially in the tablelands districts. Some of the fungicide sprays are usually combined with insecticides.

Many pear pests are the same as those described under Apple Pests, but some are common on pears and only rarely attack apples. In general, the same recommendations apply to the control of pests on both crops, but there are some situations where measures suitable to the apple require modification before being applied to the pear.

An account is given on pages 117 to 119 of the pests of pears listed below.

INSECTA		LEPIDOPTERA
Codling moth	*Cydia pomonella*	
Light-brown apple moth	*Epiphyas postvittana*	
		HYMENOPTERA
Pear and cherry slug	*Caliroa cerasi*	
		DIPTERA
Queensland fruit fly	*Dacus tryoni*	
		THYSANOPTERA
Plague thrips	*Thrips imaginis*	
		HEMIPTERA
Long-tailed mealybug	*Pseudococcus longispinus*	
San José scale	*Comstockaspis perniciosus*	
Pear root aphid	*Eriosoma pyricola*	

ARACHNIDA		ACARINA
Bryobia mite	*Bryobia rubrioculus*	
Two-spotted mite	*Tetranychus urticae*	
Pear leaf blister mite	*Phytoptus pyri*	

The following pests may be found occasionally on pears and are discussed in the sections on pests of other crops on the pages listed below.

INSECTA		LEPIDOPTERA	
Cluster caterpillar	*Spodoptera litura*		251
Leaf case moth	*Hyalarcta huebneri*		26
Loopers	*Chrysodeixis* spp.		223
Oriental fruit moth	*Cydia molesta*		126
		COLEOPTERA	
Apple root weevils	*Perperus* spp.		101
Fruit tree root weevil	*Leptopius squalidus*		39
Fuller's rose weevil	*Asynonychus cervinus*		36
		HEMIPTERA	
Black scale	*Saissetia oleae*		61
Green vegetable bug	*Nezara viridula*		232
Metallic shield bug	*Scutiphora pedicellata*		164

Codling moth *Cydia pomonella*

Codling moth on pears is usually controlled more easily than it is on apples. Infestation is more common through the calyx, although side entry is not uncommon. The extrusion of masses of dark brown excrement through the calyx end is typical.

Control measures For effective control azinphos-methyl or methidathion, each at 0.05 per cent, or carbaryl 0.1 per cent should be sprayed on pears at intervals of three weeks, beginning three weeks after petal-fall. Carbaryl may cause thinning of pears if applied less than 30 days after full bloom, however, application of carbaryl during this period should not be necessary.

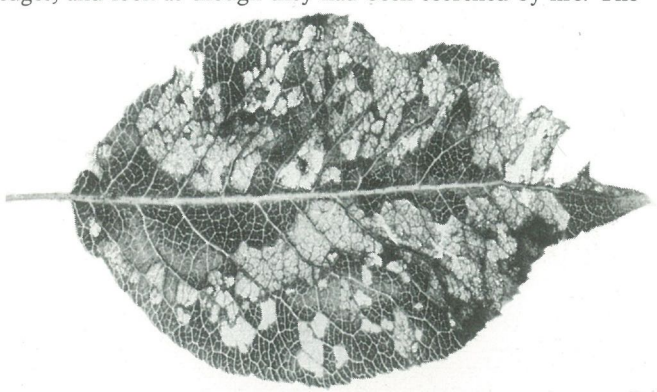
Light-brown apple moth *Epiphyas postvittana*

Pears are sometimes severely damaged, particularly the Williams variety which has thick foliage and hangs its fruit in clusters. A pronounced hardening of the flesh beneath the injured areas is characteristic of damaged pears. Control methods are described on page 96 under Apple Pests.

HYMENOPTERA

Pear and cherry slug *Caliroa cerasi*

In the coastal and tablelands areas of New South Wales, pear trees may be severely damaged by the leaf-eating larvae of this saw-fly wasp. They feed on the upper surfaces of leaves and graze the tissue so that the leaves turn brown, curl in from the edges, and look as though they had been scorched by fire. The



Leaf damaged by pear and cherry slug.

pear and cherry slug commonly attacks cherries, sometimes plums and apples, and quite often hawthorn and other ornamental shrubs. In commercial pear orchards they are of little significance, being kept in check by the spraying for codling moth. In home-garden trees they can do considerable damage in summer and autumn.

The adult is a small black wasp that lays its eggs in leaf tissue. The slug-like larvae are olive green to black, up to 12 millimetres long, and become covered with a green slime.

Control measures When control becomes necessary, it may be achieved by spraying with maldison 0.06 per cent.

For further details see page 148 under Cherry Pests.

DIPTERA

Queensland fruit fly *Dacus tryoni*

Commercial crops of pears are rarely affected by fruit fly, except sometimes on the Northern Tablelands of New South Wales. Otherwise, pears are grown in areas where the fly is uncommon or absent.

Routine spraying for codling moth also severely restricts the activities of fruit fly. When fruit fly lays eggs in pears in neglected home-garden trees, especially in coastal areas, the fruit is soon reduced to a brown rotten mass. Before the fruit rots, 'stinging' is evident from the exudation of globules of juice from the oviposition puncture and rapid coloration of the skin at that point.

Control measures Fruit fly in pears is controlled by using bait sprays or a cover spray of dimethoate or fenthion as described on page 100 for Apple Pests.

THYSANOPTERA

Plague thrips *Thrips imaginis*

Plague thrips often infest pear flowers heavily, causing obvious scorching and browning of the petals. The resulting reduction in setting of the crop is difficult to assess, but it is generally thought to be slight. Some varieties appear to be more susceptible than others, but the extensively-grown Williams variety seems to be scarcely harmed. In the notorious plague thrips year of 1931, this variety of pear set normal crops while other pears and apples were severely affected. It is doubtful whether control measures against thrips are warranted on pears.

HEMIPTERA

Long-tailed mealybug *Pseudococcus longispinus*

These insects sometimes cause damage to pears, especially in the Murrumbidgee Irrigation Area. They overwinter as adults in cracks and crevices on older trees, and move out in the spring to feed on leaves and fruit. They lodge in the calyx cavity and remain there as the calyx lobes close over. In the cavity, the mealybugs feed and breed, and secrete a sweet colourless honeydew that escapes through the calyx opening and drips from the fruit. This makes the fruit unsuitable for export, and suspect for the cannery or local market as it may suggest fruit fly or codling moth infestation. The infestation also hastens ripening, and reduces the storage life of the fruit. The problem has been more important in Victoria than in New South Wales where mealybugs are not regarded as an economic pest of pears.

San José scale *Comstockaspis perniciosus*

Pears are very susceptible to attack by this scale. Whole limbs may be killed. The rough bark protects the scales and makes it more difficult to control them.

For further details see page 107 under Apple Pests.

Pears infested heavily by San José scale.

Pear root aphid *Eriosoma pyricola*

This insect is closely related to the woolly aphid pest of apples, and has the elm as an alternate host. It is not a significant pest in New South Wales.

ARACHNIDA ACARINA

Bryobia mite *Bryobia rubrioculus*

In some seasons this pest causes considerable injury on the Williams variety in inland districts. Early feeding by the mite causes the leaves to wither and go brown. Large areas of the bark may be plastered with winter eggs.

Control measures described on page 115 under Apple Pests are effective.

Two-spotted mite *Tetranychus urticae*

These mites infest pears commonly, but it is on the Williams variety growing in hot districts that damage may be most serious and quite out of proportion to the small number of mites on the trees. 'Leaf scorch' usually follows hot dry weather in January and February, and in recent years it has been more common in some tablelands orchards than in the past. The leaves brown and curl inwards. If leaf scorch begins between about Christmas Day and mid-January, defoliation is likely to occur before harvest. This will be followed by sunburn of fruit and limbs, and possibly an autumn blossoming. This condition was unknown before DDT was used for codling moth control, so initially the blame was placed on the insecticide, the temperature at the time of DDT spraying and/or lack of soil moisture. Investigations by Turpin *et al* (1962) at Yanco showed that the trouble was a direct effect of even very small two-spotted mite populations. The situation was corrected by using an efficient miticide.

Control measures Full details of two-spotted mite control are given on page 114 under Apple Pests, except that propargite is not recommended for pears.

Leaf scorch of pear foliage resulting from two-spotted mite infestation.

Pear leaf blister mite *Phytoptus pyri*

This is a common but not very important pest of pears. It is often seen on home-garden trees, but is rarely of concern in commercial orchards. It can cause severe damage if not controlled. The first symptoms are seen in early spring when small green blisters appear on the young leaves. These blisters later turn reddish brown and finally almost black. Blisters can also form on flower stalks and on the young fruits, and cause deformed mis-shapen pears.

The adult mites are tiny, about 0.2 millimetre long, and rather worm-like with two pairs of legs at the head end. They overwinter as adults under the bud scales. In early spring they start to feed on the unfolding leaves and this causes the blisters in the leaf tissue. Eggs are laid in the blisters, and the young mites develop there. If one is opened and examined under magnification, it is seen to be full of the tiny mites. Adults move out through holes in the blisters and set up new colonies. There are many generations in the summer. In the autumn, the adults migrate to the spurs and enter the buds in which they hibernate.

Control measures The pear leaf blister mite can be controlled by spraying with lime-sulphur (polysulphides) 1 per cent at the green tip stage. Carbaryl 0.1 per cent is also effective in spring, but if it is used, early control measures against two-spotted mites will also be required. Under commercial orchard conditions, it is usually more practical to use lime-sulphur 1 per cent plus superior dormant oil 1 per cent combination spray at green tip as this treatment is also effective against bryobia mite and San José scale.

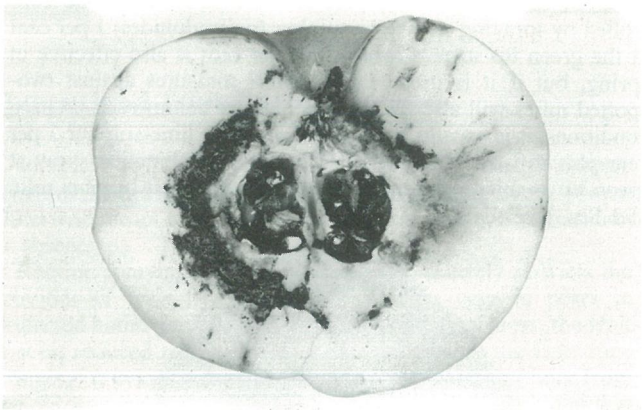
Pear leaf blister mite damage.

Quince pests

Quinces are grown commercially to only a very limited extent in New South Wales, and most plantings are in the Murrumbidgee Irrigation Area. However, quince trees are common as home-garden trees, particularly in inland districts.

Because of its long growing season, the quince provides a very suitable host for codling moth and for Queensland fruit fly in areas where the fly occurs. Where fruit fly suppression campaigns are in force, quince fruits should always be suspect as a prime refuge for maggot carry-over through the winter. Quince fruit must be removed from the trees by 30th April in each year in all areas of New South Wales.

The following pests, which are discussed under other crops, may be found in quinces in varying degrees of infestation. Control measures are generally similar to those detailed under other crops, but quinces can be injured by carbaryl sprays as used for control of codling moth on apples and pears.



Quince damaged by codling moth.

INSECTA	LEPIDOPTERA
Codling moth	*Cydia pomonella*
Leaf case moth	*Hyalarcta huebneri*
Oriental fruit moth	*Cydia molesta*
	HYMENOPTERA
Pear and cherry slug	*Caliroa cerasi*
	DIPTERA
Queensland fruit fly	*Dacus tryoni*
	COLEOPTERA
Dried fruit beetles	*Carpophilus* spp.
	HEMIPTERA
San José scale	*Comstockaspis perniciosus*
Soft brown scale	*Coccus hesperidum*
ARACHNIDA	ACARINA
A flat mite	*Brevipalpus* sp.

Loquat pests

Loquats are very seldom, if ever, grown in commercial plantings, as nearly all loquat trees are either chance seedlings or home-garden trees. They are the earliest of all fruits to ripen in the spring, and are usually prolific producers. They are of little significance in the provision of commercial fruit, but are of considerable importance in acting as an early spring host for the Queensland fruit fly. Coming out of semi-hibernation late in August, the flies find the loquat fruit available to bridge the food gap that would otherwise exist. The many flies which are bred in loquats in their season are then available to attack other fruit ripening in early summer. For the same reasons, loquats can be used as a valuable trap crop. Bait sprays applied to loquats can kill a large proportion of the fruit fly population. Young maggots can be killed effectively by spraying the trees thoroughly with dimethoate or fenthion after the fruit is well coloured.

If loquats are grown for fruit, fruit fly control can be achieved by the methods recommended for stone fruit on page 129.

Loquats infested by Queensland fruit fly.

The armoured scale dupla scale, *Duplaspidiotus claviger*, occasionally infests the trunk and limbs of the loquat. It may cause die-back of branches. The scales are brownish, but with a mealy appearance, and they form a heavy scurfy incrustation. The infestation looks like San José scale, but the insect bodies under the scales are purple, while San José scale bodies are yellow.

References

Allman, S. L. (1928). The Codling Moth. *(Cydia pomonella,* L.). Control experiments and life history observations at Bathurst, New South Wales, 1926–27. *New South Wales Department of Agriculture Science Bulletin No. 31,* 36pp.

Allman, S. L. (1931). Codling moth experiments, 1930–31. *Agricultural Gazette of New South Wales* **42**: 955–61.

Bengston, M. (1965a). Overwintering behaviour of *Tetranychus telarius* (L.) in the Stanthorpe district, Queensland. *Queensland Journal of Agricultural and Animal Sciences* **22**: 169–76.

Bengston, M. (1965b). European red mite (*Panonychus ulmi* (Koch)) and its adaptation to the Stanthorpe district, Queensland. *Queensland Journal of Agricultural and Animal Sciences* **22**: 177–85.

Bower, C. G. (1977). European red mite – apple pest in N.S.W. *Agricultural Gazette of New South Wales* **88**: 5:40–41.

Boyle, W. W. (1957). On the mode of dissemination of the two-spotted spider mite, *Tetranychus telarius* (L.) (Acarina: Tetranychidae). *Proceedings of the Hawaiian Entomological Society* **16**: 261–8.

Brookes, H. M. and Hudson, N. M. (1968). The identification and distribution of *Quadraspidiotus* species (Homoptera: Diaspididae) on pome and stone fruits in Australia. *Journal of the Australian Entomological Society* **7**: 90–100.

Clark, D. P. (1967). A population study of *Phaulacridium vittatum* Sjöst. (Acrididae). *Australian Journal of Zoology* **15**: 799–872.

Dumbleton, L. J. (1932). The apple leaf-roller (*Tortrix postvittana* Walker). *New Zealand Journal of Science and Technology* **14**: 83–92.

Dumbleton, L. J. and Jeffreys, F. J. (1938). The control of the woolly aphis by *Aphelinus mali. New Zealand Journal of Science and Technology* **20**: 183–90.

Evans, J. W. (1932). The Bionomics and Economic Importance of *Thrips imaginis* Bagnall, with Special Reference to Its Effect on Apple Production in Australia. *Council for Scientific and Industrial Research Pamphlet No. 30.* 48pp.

Froggatt, W. W. (1901). The codling moth (*Carpocapsa pomonella*, Linn.). *Agricultural Gazette of New South Wales* **12**: 1354–62.

Froggatt, W. W. (1920). Three native beetles attacking orchard trees. *Agricultural Gazette of New South Wales* **31**: 421–6.

Geier, P. W. (1963a). The life history of codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), in the Australian Capital Territory. *Australian Journal of Zoology* **11**: 323–67.

Geier, P. W. (1963b). Wintering and spring emergence of codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), in South Eastern Australia. *Australian Journal of Zoology* **11**: 431–45.

Geier, P. W. (1964). Population dynamics of the codling moth, *Cydia pomonella* (L.) (Tortricidae), in the Australian Capital Territory. *Australian Journal of Zoology* **12**: 381–416.

Geier, P. W. (1965). Conditions of management of two orchard pests, one exotic and the other native to south-eastern Australia. *Proceedings of the 12th International Congress of Entomology, London, 1964,* p598.

Geier, P. W., Hillman, T. J. and Wilson, A. G. L. (1967). Evaluating new prospects in pest control. *Journal of the Australian Entomological Society* **6**, 91–102.

Gibson, F. A. (1966). A survey of spider mites of deciduous fruit trees in New South Wales. *The Australian Journal of Science* **29**: 21.

Hough, W. S. (1962). Toxicity of some insecticides to larvae of codling moth after they enter apples. *Journal of Economic Entomology* **55**: 378–81.

Johnson, J. F., Lloyd, N., Holligan, P., Gilbert, W. S., Trimmer, W., Thwaite, G., Glennie-Holmes, M., Whiston, D. and Richens, K. (1972). Two-spotted mite control can be improved. *Agricultural Gazette of New South Wales* **83**: 294–7.

Key, K. H. L. (1939). How To Recognise the Locusts and Grasshoppers of Economic Importance in Australia. *Council for Scientific and Industrial Research*, Canberra. 16pp.

Kremer, F. W. (1956). Studies on the biology, epidemiology and control of *Bryobia praetiosa. Höfchen – Briefe* **9**: 189–252.

Lloyd, N. C. (1952). The fruit tree bud weevil. A pest of young fruit trees in the Orange district. *Agricultural Gazette of New South Wales* **63**: 90–92, 99.

Lloyd, N. C. (1959). Red mite (*Bryobia praetiosa*). *Agricultural Gazette of New South Wales* **70**: 245–7.

Lloyd, N. C. (1960). The light brown apple moth. A pest of deciduous fruits in New South Wales. *Agricultural Gazette of New South Wales* **71**: 32–4.

Lloyd, N. C. (1961). Codling moth (*Cydia pomonella*). *Agricultural Gazette of New South Wales* **72**: 96–100.

Lloyd, N. C. (1961). The woolly apple aphid. *Agricultural Gazette of New South Wales* **72**: 652–4, 659.

Lloyd, N. C. (1962). The red spider. A serious pest of deciduous fruit trees. *Agricultural Gazette of New South Wales* **73**: 544–9.

Lloyd, N. C. (1969). The apple dimpling bug *Campylomma livida* Reut. (Hemiptera: Miridae). *Agricultural Gazette of New South Wales* **70**: 582–4.

Lloyd, N. C., Jones, E. L., Morris, D. S., Webster, W. J., Harris, W. B., Lower, H. F., Hudson, N. M. and Geier, P. W. (1970). Managing apple pests: a new perspective. *Journal of the Australian Institute of Agricultural Science* **36**: 251–8.

Madsen, H. F., Myburgh, A. C., Rust, D. J. and Bosman, I. P. (1974). Codling moth (Lepidoptera: Olethreutidae): correlation of male sex attractant trap captures and injured fruit in South African apple and pear orchards. *Phytophylactica* **6**: 185–7.

Melander, A. L. (1914). Can insects become resistant to sprays? *Journal of Economic Entomology* **7**: 167–73.

Miller, L. W. (1953). The control of mites in Tasmanian apple orchards. *Tasmanian Journal of Agriculture* **24**: 347–57.

Morris, D. S. (1966). The light brown apple moth. *Journal of Agriculture, Victoria* **64**: 23–6, 31.

Olliff, A. S. (1892). The codling moth *Carpocapsa pomonella* Linn. Its life history and habits. *Entomological Bulletin* No. 1. Department of Agriculture, Sydney, New South Wales.

Proverbs, M. D., Newton, J. R. and Logan, D. M. (1969). Codling moth control by releases of radiation-sterilized moths in a commercial apple orchard. *Journal of Economic Entomology* **62**: 1331–4.

Quayle, H. J. (1938). *Insects of Citrus and Other Subtropical Fruits.* Comstock Publishing Co., Ithaca, N.Y. 583pp.

Smith, L. C. (1955). DDT-resistant codling moth: a report on the 1954/55 control trials. *Journal of the Department of Agriculture, South Australia* **59**: 12–15.

Thwaite, W. G. (1976). Codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae): flight records for eight seasons at Bathurst, N.S.W. *Journal of the Entomological Society of Australia (N.S.W.)* **9**: 43–6.

Timlin, J. S. (1964). The biology, bionomics and control of *Parlatoria pittospori* (Mask.) (Hemiptera: Diaspididae): a pest of apples in New Zealand. *New Zealand Journal of Agricultural Research* **7**: 536–50.

Turpin, J. W., Jones, E. L. and Sidlow, J. M. (1962). Leaf scorch of pears. *Agricultural Gazette of New South Wales* **73**: 468–70, 486–8.

Vevers Steele, H. (1935). Thrips Investigation: Some Common Thysanoptera in Australia. *Council for Scientific and Industrial Research Pamphlet No. 54.*

Wason, E. J. and Lloyd, N. C. (1949). Pests of pome fruit trees. *Agricultural Gazette of New South Wales* **60**: 479–81.

Watt, M. J. (1965). Notes on pests of stored grain. *Liposcelis bostrychophilus* and *Sitophilus* spp. *Agricultural Gazette of New South Wales* **76**: 693–6.

Wilson, F. (1960). *A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea.* Technical Communication No. 1, Commonwealth Institute of Biological Control, Ottawa, Canada. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks., England. 102pp.

STONE FRUITS

Stone fruits pests

Stone fruits – peaches and nectarines, almonds, plums and prunes, apricots and cherries – may be infested by a large number of insect and mite pests, many of which are common to more than one stone fruit species. However, their importance can vary among the different fruit species.

The major and minor pest species of stone fruits are listed in alphabetical order below.

ARTHROPODA

INSECTA

LEPIDOPTERA

Budworms	*Heliothis* spp.
Codling moth	*Cydia pomonella* (Linnaeus)
Cup moths	*Doratifera* spp.
Fruit tree borer	*Cryptophasa melanostigma* (Wallengren)
Leaf case moth	*Hyalarcta huebneri* (Westwood)
Light-brown apple moth	*Epiphyas postvittana* (Walker)
Oriental fruit moth	*Cydia molesta* (Busck)
Painted apple moth	*Teia anartoides* Walker
A tussock moth	*Porthesia paradoxa* (Butler)
Yellow peach moth	*Dichocrocis punctiferalis* (Guenée)

HYMENOPTERA

Pear and cherry slug	*Caliroa cerasi* (Linnaeus)

DIPTERA

Queensland fruit fly	*Dacus tryoni* (Froggatt)

COLEOPTERA

African black beetle	*Heteronychus arator* (Fabricius)
Apple root weevils	*Perperus* spp.
Apple weevil	*Otiorhynchus cribricollis* Gyllenhall
Christmas beetles	*Anoplognathus* spp.
Dried fruit beetles	*Carpophilus* spp.
Elephant weevil	*Orthorhinus cylindrirostris* (Fabricius)
Fruit tree pinhole borer	*Xyleborus saxeseni* (Ratzeburg)
Fruit tree root weevil	*Leptopius squalidus* (Boheman)
Fuller's rose weevil	*Asynonychus cervinus* (Boheman)
Monolepta beetle	*Monolepta australis* (Jacoby)
Pumpkin beetle	*Aulacophora hilaris* (Boisduval)
Soldier beetle	*Chauliognathus lugubris* (Fabricius)
Vine weevil	*Orthorhinus klugi* Boheman

THYSANOPTERA

Greenhouse thrips	*Heliothrips haemorrhoidalis* (Bouché)
Plague thrips	*Thrips imaginis* Bagnall

HEMIPTERA

Apple leafhopper	*Typhlocyba froggatti* Baker
Black peach aphid	*Brachycaudus persicae* (Passerini)
Cherry aphid	*Myzus cerasi* (Fabricius)
Cicadas	Cicadidae
Coon bug	*Oxycarenus arctatus* (Walker)
Frosted scale	*Eulecanium pruinosum* (Coquillet)
Fruit-spotting bug	*Amblypelta nitida* Stål
Grapevine scale	*Parthenolecanium persicae* (Fabricius)
Green mirid	*Creontiades dilutus* (Stål)
Green peach aphid	*Myzus persicae* (Sulzer)
Green stink bug	*Plautia affinis* Dallas
Green vegetable bug	*Nezara viridula* (Linnaeus)
Metallic shield bug	*Scutiphora pedicellata* (Kirby)
Pale cotton stainer	*Dysdercus sidae* Montrouzier
Peach white scale	*Pseudaulacaspis pentagona* (Targioni-Tozzetti)
Rutherglen bug	*Nysius vinitor* Bergroth
San José scale	*Comstockaspis perniciosus* (Comstock)

ORTHOPTERA

Citrus katydid	*Caedicia strenua* (Walker)
Inland katydid	*Caedicia simplex* (Walker)
Wingless grasshopper	*Phaulacridium vittatum* (Sjöstedt)

ARACHNIDA

ACARINA

Bryobia mite	*Bryobia rubrioculus* (Scheuten)
European red mite	*Panonychus ulmi* (Koch)
Peach silver mite	*Aculus cornutus* (Banks)
Two-spotted mite	*Tetranychus urticae* Koch

Peach and nectarine pests

Peaches and, in much smaller numbers, nectarines are grown in New South Wales in coastal, tablelands and inland districts. Most of the commercial production in coastal areas is not far distant from Sydney and Newcastle and consists of early or second-early varieties for the dessert peach market. Mid-season dessert varieties are mainly grown in tableland areas. In the Murrumbidgee Irrigation Area there are extensive plantings of mid-season or late-maturing varieties for canning.

Many of the pests are common to all districts, but the intensity of infestation of major pests may vary from district to district. The susceptibility of trees to damage from the use of certain spray materials can differ with varieties. Early varieties, such as Watts Early, are extremely susceptible to injury by some sprays, particularly maldison and dimethoate. This susceptibility to spray injury is reduced in later-maturing varieties, so that canning peaches may be sprayed at temperatures which would be most damaging to the early dessert types.

Development of the crop varies with the district. In the earliest varieties the first sign of bud development may be seen as pinking towards the end of June while blossoming occurs in July, but for the main peach-growing districts the following is an approximate phenological table.

Budswell	– late July to early August
Pinking	– mid- to late August
Full bloom	– early to mid-September
Petal-fall	– late September
Shuck-fall	– early to mid-October
Harvest	– late November to December for early varieties – January to February for mid-season varieties – February to March for late varieties
Leaf-fall	– late April to late May
Dormant period	– late May to late July (except for early coastal district trees)

An account is given on pages 126 to 138 of the pests of peaches and nectarines listed below.

INSECTA

LEPIDOPTERA

Oriental fruit moth	*Cydia molesta*
Yellow peach moth	*Dichocrocis punctiferalis*
Budworms	*Heliothis* spp.
Light-brown apple moth	*Epiphyas postvittana*
Fruit tree borer	*Cryptophasa melanostigma*
A tussock moth	*Porthesia paradoxa*

DIPTERA

Queensland fruit fly	*Dacus tryoni*

COLEOPTERA

Dried fruit beetles	*Carpophilus* spp.
Apple weevil	*Otiorhyncus cribricollis*

THYSANOPTERA

Plague thrips	*Thrips imaginis*

HEMIPTERA

Green peach aphid	*Myzus persicae*
Black peach aphid	*Brachycaudus persicae*
San José scale	*Comstockaspis perniciosus*
Frosted scale	*Eulecanium pruinosum*
Peach white scale	*Pseudaulacaspis pentagona*
Fruit-spotting bug	*Amblypelta nitida*
Green vegetable bug	*Nezara viridula*
Rutherglen bug	*Nysius vinitor*
Coon bug	*Oxycarenus arctatus*
Green mirid	*Creontiades dilutus*
Cicadas	Cicadidae

ORTHOPTERA

Wingless grasshopper	*Phaulacridium vittatum*
Inland katydid	*Caedicia simplex*
Citrus katydid	*Caedicia strenua*

ARACHNIDA

ACARINA

Bryobia mite	*Bryobia rubrioculus*
Two-spotted mite	*Tetranychus urticae*
Peach silver mite	*Aculus cornutus*

The following less important pests of peaches and nectarines are discussed in the sections on pests of other crops on the pages listed below.

INSECTA

COLEOPTERA

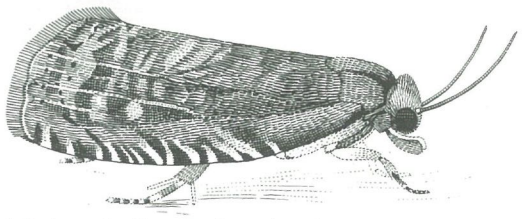
African black beetle	*Heteronychus arator*	295
Apple root weevils	*Perperus* spp.	101
Elephant weevil	*Orthorhinus cylindrirostris*	37
Fuller's rose weevil	*Asynonychus cervinus*	36
Fruit tree root weevil	*Leptopius squalidus*	39
Monolepta beetle	*Monolepta australis*	43

HEMIPTERA

Green stink bug	*Plautia affinis*	234
Metallic shield bug	*Scutiphora pedicellata*	164

INSECTA LEPIDOPTERA

Oriental fruit moth *Cydia molesta*



Oriental fruit moth. (Length about 6 mm)

Importance and Distribution The oriental fruit moth or peach tip moth is a pest in Asia, Europe, and North and South America (Allen, 1958), and has been known in New South Wales since the early 1900s (Froggatt, 1914). Since then it has spread throughout the State. It is of special importance in the coastal region north of Sydney as a pest of dessert peaches, and in the canning peach industry in the Murrumbidgee Irrigation Area. It was first reported in the M.I.A. at Griffith in 1936, even though it was already a well-known pest in the Goulburn Valley, Victoria. Efforts were made to limit its spread in the M.I.A., but it was found to be established in Leeton in 1950.

Oriental fruit moth damages both twigs and fruit. Dead blackened peach tips, usually with blobs of clear gum, are characteristic of the spring infestation. However, it is of the greatest importance as a pest of fruit, because the presence of any insects in canned fruits is unacceptable. Canners enforce strict controls to avoid the delivery of infested fruit. Sorting infested fruit at the cannery, particularly if it is infested through the stem end, adds greatly to the costs.

Conditions for Infestation Warm and fairly moist conditions that promote lush twig growth encourage populations of the moth to build up quickly. These conditions also favour the brown rot fungus which is frequently associated with oriental fruit moth – an association that greatly increases the total damage. Hot dry windy weather is quite unfavourable to the moth. Even if a heavy infestation is threatened in spring, hot winds in the summer can almost remove the trouble. Very cold winters are also unfavourable to the pest.

Plants attacked Peach and nectarine are the fruit trees most subject to attack, as also are ornamental varieties of those trees. Plum, prune, apricot, cherry, apple and pear are recorded as hosts, but damage to them is rarely important. Quinces are commonly attacked late in the season and may be important contributors to the carry-over of overwintering larvae.

Description and Life History The adults measure about 12 millimetres across the outspread wings. They are generally grey in colour, and the front margins of the forewings have narrow light or white bars. They fly mainly at night and are seldom seen by day. The eggs are white or cream, round or oval, and less than 1 millimetre in diameter. The full-grown larva is about 12 millimetres long, and creamy or pink with a light brown head. It is similar to the codling moth larva, but is distinguished from it by having a five-toothed comb-shaped plate on the dorsal surface of the last body segment.

Moths from the overwintering generation begin to emerge early in September, or even earlier in coastal orchards, and continue to appear until the end of October. Moths which develop from the eggs laid by the overwintering generation begin to emerge in November. In summer the complete life cycle from egg to adult takes about 36 days. There may be as many as six generations in a year, but only four or five are more usual. Moths emerging in the autumn lay eggs and most of the resulting larvae die, but those which infest quinces late in the season tend to survive. Broods overlap one another; eggs, larvae of various sizes, pupae and adults may be present together in an orchard from September to April (Jones, 1967).

The moths deposit eggs on the undersides of leaves or on smooth stems close to young shoots or fruits. After hatching, the young larva may enter tips if suitable succulent tissue is available, or they may attack green fruit. The twigs are usually entered near the tip and one grub may attack as many as five shoots in its feeding period. On selecting a spot to enter the twig, the larva spins a web about itself and tunnels into the plant. After discarding the first few mouthfuls it may tunnel 8 to 10 centimetres down the shoot, causing the tip to wilt and die. When an older larva enters a new shoot it may do so at the axil of a leaf below the tip. Larvae in shoots are sometimes killed by becoming smothered in gum. The successful larva eats its way out of the shoot and finds a fold of a leaf, loose or lifted bark, or a crack in a limb in which to spin its cocoon.

The first two broods of the year mostly spin their cocoons high in the trees. Larvae of later generations crawl down the tree to fix their cocoons under rough bark on the trunk, or away from the tree under plant debris or in crevices in the soil, or in mummified fruits. These later cocoons, designed for overwintering, are thicker and stronger than spring and summer ones, and often have particles of bark, peach fur and leaf fragments built into them.

When fruit is attacked the point of entry is usually at the stem end, but it may be where a leaf or twig touches a fruit. After entering the fruit the larva tunnels to the stone and may extend around it. Brown excrement, and often gum if the fruit is green, will be found at the point of entry.

Injury Tip injury to young trees interferes with the proper shaping of the trees. It is more important that breeding in the twigs in spring builds up the summer broods which attack the fruit. When fruit that is nearly ripe is attacked, the direct injury is often aggravated by the development of brown rot. Infestation of almost-ripe fruit is encouraged by wet weather and this also helps the brown rot. The combined damage in a wet summer can be great.

Fruit damage varies from orchard to orchard and from season to season, and its likely extent is difficult to predict. In the Murrumbidgee Irrigation Area a warning service is maintained. Traps baited with terpinyl acetate and sucrose, supplemented by synthetic pheromone lure traps, are placed in orchards known to have high populations of oriental fruit moth, and these are serviced regularly. Reports of any substantial emergence of moths, based on orchard observations, trap catches, and temperature records, are made to growers by broadcasting or through the press.

Dispersal Movement through the orchard is by the flight of moths in the evening, but they are not strong fliers. Young nursery trees can carry infestations, and dispersal from orchard to orchard in picking boxes is possible.

Control measures

NATURAL Several primary parasites attack the larvae and pupae, and probably keep the population in check to some de-

Oriental fruit moth
Cydia molesta

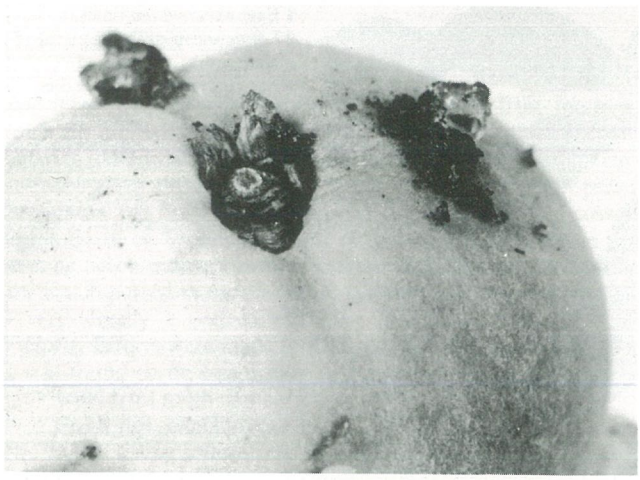
1 Egg; enlarged ten times. **2** Larva or caterpillar; **3** pupa; **4** adult moth; all enlarged about eight times. **5** Twig die-back caused by caterpillars feeding within the tips.

gree. Helson (1939) recorded parasitism by the wasp *Dibrachys cavus* (Walker) of up to 90 per cent on overwintering larvae around the butts of trees late in the season in the Goulburn Valley. Several other wasps attack oriental fruit moth in New South Wales. In the United States *Macrocentrus ancylivorus* Rohwer has been bred artificially and liberated to control this moth. When introduced and liberated in the Goulburn Valley and the Murrumbidgee Irrigation Area in 1935–40 it did not show any significant effect, and it is considered not to have become established (Wilson, 1960).

APPLIED Infested fruit should be destroyed every few days by boiling, burning or deposition in an insect-proof pit. Loose or rough bark, which provides cocooning sites, should be removed from the trees.

Control is based on spraying the trees thoroughly with azinphos-methyl 0.05 per cent, or carbaryl 0.1 per cent, or fenthion 0.05 per cent, preferably timed to coincide with periods of greatest moth activity. Spraying should begin within fourteen days of petal-fall and be repeated at intervals of three weeks. When a warning service gives information based on trap catches, the interval can be extended beyond three weeks. The use of any of the sprays may result in an increase of two-spotted mites, so special attention to mite control spraying can become essential. Infestation on non-fruiting young trees should be controlled to preserve the development of the trees and prevent a build-up of

moth numbers. In home-garden trees the cutting-off and burning of infested tips, beginning early in spring, will reduce damage. Infested fruits should also be destroyed.



Peach damaged by oriental fruit moth.

Oriental fruit moth damage to peach shoots.

Yellow peach moth *Dichocrocis punctiferalis*

This insect is widely distributed throughout South East Asia, and attacks a variety of crops including citrus, maize, pawpaw, mango, custard apple and cotton, as well as peach. As a subtropical species, it is confined to the Far North Coast area and is not found in the commercially important peach-growing areas of New South Wales. The injury generally occurs when the fruit is nearly ripe. The grubs bore in where two fruits hang together or at the stem end. They usually feed around the stone, and fill the cavity formed with dark brown frass pellets. If the fruit is green, there is often a considerable exudation of clear gum.

The eggs are oval-shaped. The caterpillars become full-fed in about three weeks in summer, being then about 18 millimetres long and greyish white often tinged with pink. The head is dark and there is a dark 'shield' on the upper surface of the first body segment. The larvae pupate on the host plant, and the moths emerge two weeks later. They are attractive and bright yellow or orange with a wing span of about 2.5 centimetres. The wings and body have a number of conspicuous black spots.

Control measures If control measures for yellow peach moth become necessary, those for oriental fruit moth will probably be effective (page 126).

Budworms *Heliothis* spp.

In some years during spring these caterpillars move from herbage in the orchard to the trees and damage young fruits. This behaviour and necessary control measures are discussed under Apple Pests on page 99, while the life history details are given under Bean Pests on page 219.

Light-brown apple moth *Epiphyas postvittana*

In some seasons these caterpillars do serious damage to peaches by surface-feeding on ripening fruit at the points where fruits are in contact or under the protection of a touching leaf. Leaf injury is more likely to be found low down in the centre of the trees. The damaged leaves have a ragged appearance and are often webbed together in clusters.

Control measures Azinphos-methyl 0.05 per cent, carbaryl 0.05 per cent or fenthion 0.05 per cent spray will control this pest.

Further details will be found under Apple Pests on page 96.

Fruit tree borer *Cryptophasa melanostigma*

Larvae of this moth feed on the bark of limbs and bore tunnels into the wood beneath it. The site is usually at a fork and is marked by a mass of dark brown pellets which are entangled under light webbing.

This pest is described more fully under Plum and Prune Pests on page 141.

A tussock moth *Porthesia paradoxa*

In coastal districts, ripening peaches and nectarines are sometimes damaged when the hairy brown and red larvae of this snow white moth graze on the fruit surface near the stem. The grubs reach a length of about 2.5 centimetres. Each has a pair of reddish prominences on the back towards the rear end.

Control measures If necessary, the invasion may be controlled by spraying with carbaryl 0.1 per cent.

DIPTERA

Queensland fruit fly *Dacus tryoni*

The fly can largely destroy a home-garden crop of late peaches, but does comparatively little damage in commercial orchards due to the regular orchard management practices and control measures. Some of the early varieties may increase the fly population in spring, but usually only a low proportion of such crops is attacked. Early-maturing varieties, such as Watts, Starking Delicious, Maygold and Coronet, often escape serious attack.

Control measures Some of the early peaches are liable to be injured by dimethoate cover spray, so 0.03 per cent fenthion cover spray is recommended for application four weeks and three weeks before ripening. For later peaches either dimethoate 0.03 per cent or fenthion 0.03 per cent is suitable if applied four weeks and three weeks before ripening.

For all peaches protein hydrolysate-maldison bait spray, as described under Citrus Pests on page 34, is recommended and it may be used with or without cover-spraying. Bait-spraying should begin five weeks before the variety ripens or at the first sign of 'stinging' if this is earlier, and continue until four weeks after harvesting.

The pest is discussed more fully under Citrus Pests on page 31 and Apple Pests on page 100.

COLEOPTERA

Dried fruit beetles *Carpophilus* spp.

Importance and Distribution Several species of this genus are pests of stored products and dried fruits, and are known to infest fruits on drying trays. The adult beetles are attracted over long distances to rotting fruit or vegetables. Dried fruit beetles can seriously damage ripening peaches both by their feeding and by carrying spores of brown rot fungus. Several species of dried fruit beetles are known to attack fruit in coastal regions (Gaven, 1964) – *Carpophilus mutilatus* being the most abundant – while other species cause damage to crops in the Murrumbidgee Irrigation Area. Crop losses in coastal regions due to these beetles range from 5 per cent to 25 per cent (Gaven, 1964).

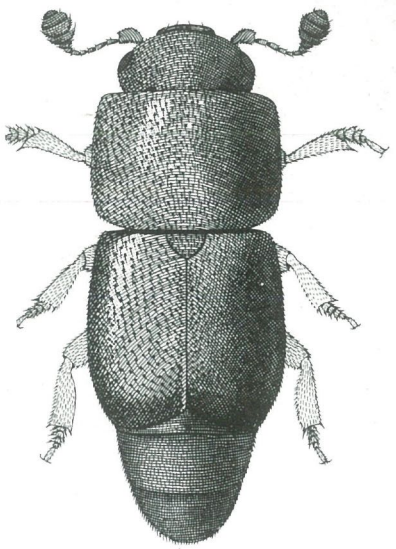
Conditions for Infestation Warm moist seasons with an abundance of fermenting fruit favours a population build-up of these beetles. While dry hot conditions deprive the beetles of much potential food, deep layers of rotting fruit or vegetables can still remain moist for long enough for the beetles to breed.

Plants attacked Most varieties of fruits and vegetables will serve as breeding media for dried fruit beetles especially while they are drying. Of the fresh fruit, peaches, nectarines, figs and apricots are the most affected.

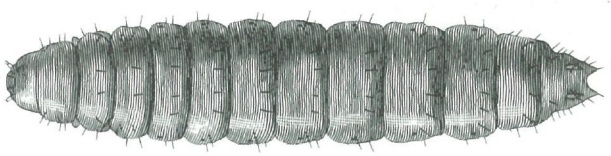
Description and Life History The adult beetles are small, about 3 millimetres long, and elongate-oval in outline. They are somewhat flattened and have short wing covers that do not reach the tip of the abdomen. They are usually brown or black with paler colouring on the wing covers. They run or fly readily when disturbed. The egg is white, elongated and slightly curved. The newly-hatched larva is about 1.5 millimetres long and white or almost translucent. It grows to a length of 6.5 millimetres and is yellowish, elongate and slender, with a light brown head and forked tail. It has three pairs of short legs and moves quickly when disturbed.

All stages can be found at most times of the year. They overwinter as adults in cracks and crevices or under bark; as adults and larvae within rotting fruits such as apples and citrus fallen to the ground or still hanging on trees; or as larvae, pupae or adults in the soil. They develop rapidly in warm months and produce many generations each year. Gaven (1964) found that at temperatures ranging from 16°C to 22°C eggs, larvae and pupae required respectively an average of five, 31 and 23 days to develop.

Eggs are usually laid in rotting fruit which is either still hanging or on the ground. Less commonly they are laid in skin breaks, caused by the attacks of other insects, in hanging fruit. Trapping experiments have shown that in peach orchards in the Murrumbidgee Irrigation Area most beetles are taken from mid-October to the end of November. Catches are low during the apricot harvest when beetles are attracted more to the ripe fruits than to lure traps. Trapping figures rise again through January to reach another peak in early February, before the peach harvest (Anon, 1966). The beetles will migrate to whatever fruit is nearly ripe.



A dried fruit beetle. (Length about 3 mm)



Larva of a dried fruit beetle, seen from above. (Length, when fully developed, about 6.5 mm)

Injury The extent of the injury caused directly by dried fruit beetles to stone fruits varies from year to year, but they also play an important part in the epidemiology of brown rot disease (Kable, 1969a). Fruit loss is caused primarily by beetles burrowing into ripening fruit, commonly through surface splits or by penetrating near the stem end on the suture line, and this is followed by rotting. Beetles rarely penetrate the exposed surfaces of the fruit.

Dispersal The beetles are strong fliers. In California, flights of 4 kilometres have been recorded (Lindgren and Vincent, 1953). In an orchard they appear very quickly wherever fruit is decaying.

Control measures

NATURAL Little is known of the natural enemies of dried fruit beetles.

APPLIED Destruction of waste fruit is the first and most important step. Large numbers of beetles in fallen fruit can be destroyed by burning or boiling it, or by putting it in an insect-proof pit.

An efficient programme to control fruit fly, oriental fruit moth and light-brown apple moth undoubtedly greatly reduces the volume of damaged and fermenting fruit available to the beetles.

Maldison 0.1 per cent sprayed over the trees at intervals of a few days, while fruit is attracting the beetles, can be effective.

Apple weevil *Otiorhynchus cribricollis*

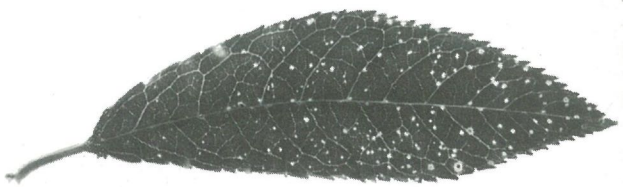
These weevils occur in the southern part of New South Wales. They chew the edges of leaves, producing a saw-toothed effect, and may cause heavy leaf-fall. For further details see under Citrus Pests on page 40.

THYSANOPTERA

Plague thrips *Thrips imaginis*

These tiny narrow-bodied insects, which are light brown and winged in the adult stage or yellow and wingless in the immature stages, occur in huge numbers in some years during the spring. They infest the flowers of many trees, garden plants and weeds, as well as fruit trees. While plague thrips are frequently found in peach and nectarine flowers, their effect on the fruit setting of these crops is generally thought to be unimportant. They do, however, cause considerable skin-blemishing on the smooth-skinned nectarines and a much smaller amount of blemishing on peaches. Sometimes they produce a shot-hole effect in young peach leaves as a result of their egg-laying, and some curling of the leaves.

Nectarine which was blemished as a newly-set fruit by plague thrips.



Shot-hole effect in peach leaf from egg-laying of plague thrips.

Investigations by Allman (1948) in the Hills district on Goldmine nectarines proved the association between thrips infestation in the spring and surface-blemishing of the mature fruit and showed that timely spraying could substantially reduce the blemishing.

After petal-fall, nectarines and some peaches retain the other flower remnants for some weeks on the developing fruits. The growth of the fruit splits the drying floral tube or shuck which is then shed when the fruit is 6 to 12 millimetres in diameter. This shedding is commonly called 'shuck-fall'. Young thrips shelter and feed for several weeks under cover of the shuck. Even when they are only few in number the prolonged feeding on tender tissue results in a skin-blemishing of the ripe fruit. There is russeting in varying degrees and some malformation. The fruit may be deeply grooved, often flattened, and perhaps cracked, but it is more usual to see a network pattern of thin brown corky marks in the skin.

Control measures Control may be achieved and blemishing reduced to insignificance by spraying with DDT 0.1 per cent as an emulsifiable concentrate when most of the petals have fallen, usually about the end of September or early October.

Further details will be found under Apple Pests on page 102.

Green peach aphid *Myzus persicae*

Importance and Distribution This aphid has a world-wide distribution and a large number of host plants. It was first recorded in New South Wales in 1910 (Zeck, 1928). It was a peach pest of major significance wherever the crop was grown in this State until good control measures were developed. Green peach aphid threatened to cripple the peach-growing industry in the Murrumbidgee Irrigation Area, but because of the good control measures now available it is a pest of secondary importance.

Conditions for Infestation Abundant growth of herbaceous weeds in the previous summer and autumn, late leaf-fall from the peach trees, and a cool wet spring are the conditions most likely to lead to severe damage by green peach aphid in spring. Cold damp spring weather slows down the hardening of early peach growth, and delays the appearance of the natural enemies of the aphid.

Plants attacked Fruit tree hosts include almonds and some plums, as well as peach and nectarine. The secondary hosts include capeweed, dock, Iceland poppies, peas, roses, sow thistles, tomatoes, potatoes, cabbage and many other plants.

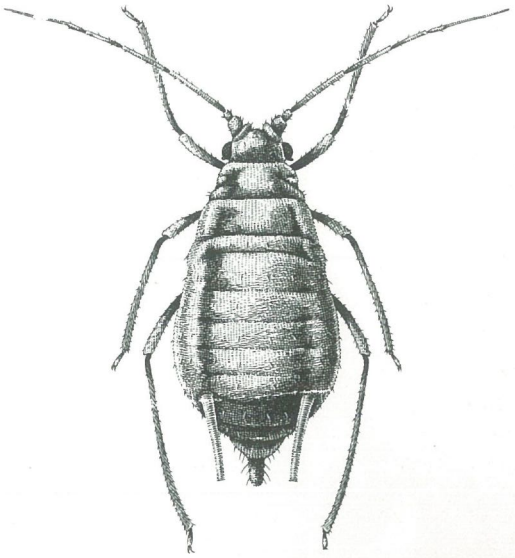
Description and Life History Where winters are cold the aphids overwinter as eggs on the primary host – the peach. These eggs hatch to produce wingless, yellowish green, plump stem mothers that give rise to several generations of wingless females 2.3 millimetres long which feed and breed (by producing active young, not eggs) in late winter and early spring. When the weather warms up and the peach foliage hardens off early in October, or even in November if the weather is cool, the aphid colonies produce 'spring migrant' females with wings. They are darker green than the wingless females, have brown markings, an almost black thorax and dark red eyes. They move to secondary herbaceous host plants, produce wingless colonies, and breed there through summer and autumn.

In late April 'autumn migrant' females are produced that fly from the secondary hosts to the peach trees. They settle on the peach leaves that are beginning to change colour. The 'autumn migrants' on the peach leaves produce wingless oviparous females which, when mature, are fertilized by 'autumn migrant' winged males. The fertilized wingless females on the peach leaves move back to the laterals and deposit eggs behind the buds. Most overwintering eggs are laid on the tips of laterals because these bear the leaves that fall last. If conditions are thoroughly in favour of the aphid, eggs may be found on all parts of the tree, and even on props and stakes. The eggs are green when fresh but they become jet black and shiny. The eggs begin to hatch as early as the end of June, but nymphs from such eggs remain quiescent until the buds begin to swell in early August.

In milder climates, there is no egg stage and the aphids breed throughout the year on secondary hosts, occasionally producing winged forms which fly to other secondary hosts.

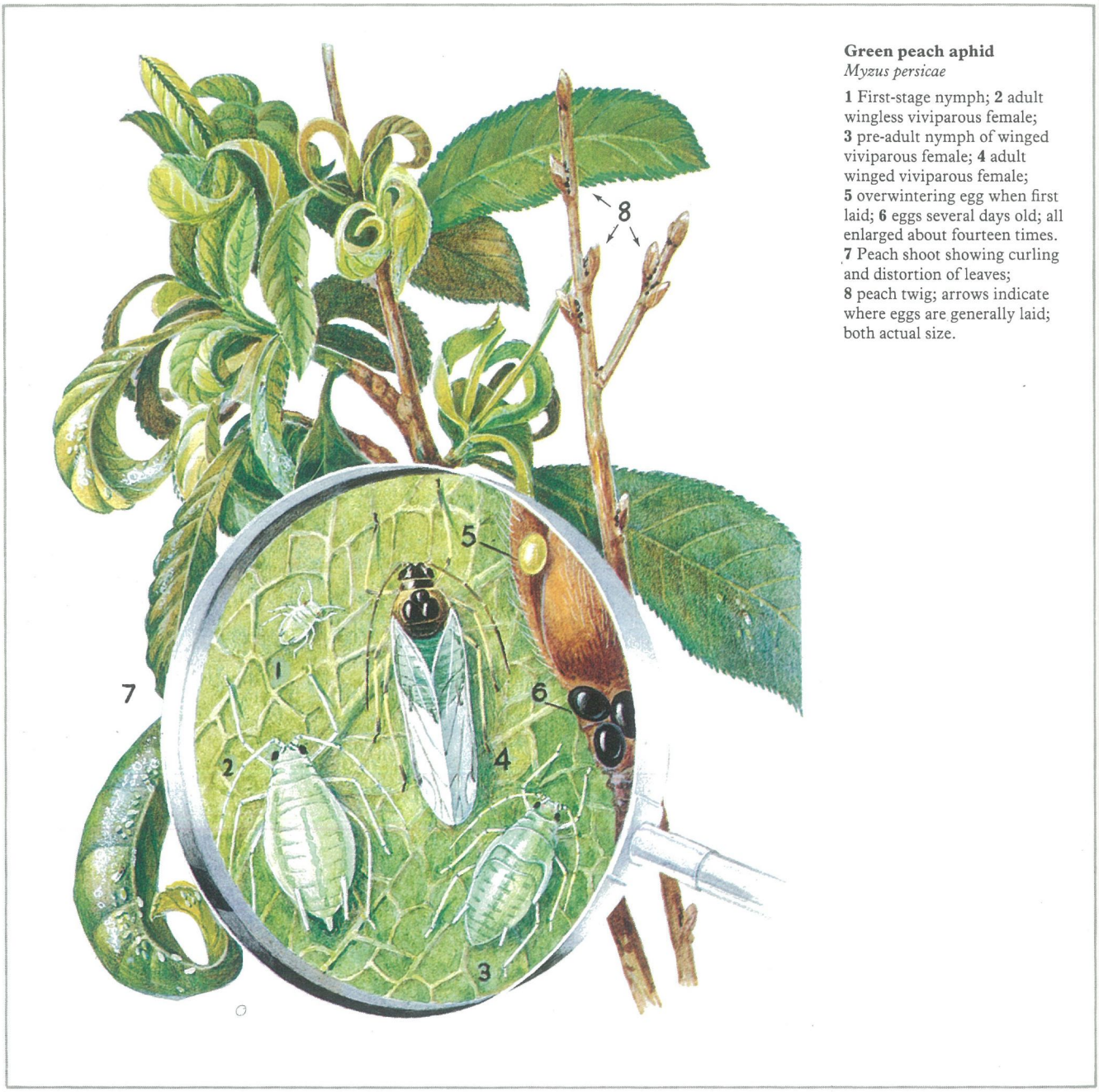
Injury Destruction of the opening buds and blossoms by the stem mothers and the succeeding generation may reduce fruit setting. The feeding by stem mothers on swelling buds often causes premature opening of the flowers – a single petal emerging from the bud indicates the presence of green peach aphid. The succeeding generation feeds on the flower parts before the petals unfold fully, and opening buds and blossoms are contorted and fall readily.

Following this the aphids move to the new leaves and to young fruit, much of which falls. The main damage is caused by feeding on the young leaves and laterals. The leaves become



Green peach aphid – wingless female. (Length 2.3 mm)

Green peach aphid – winter eggs around buds on peach lateral.
P.R.I., Dept of Ag. Vic.



Green peach aphid
Myzus persicae

1 First-stage nymph; **2** adult wingless viviparous female; **3** pre-adult nymph of winged viviparous female; **4** adult winged viviparous female; **5** overwintering egg when first laid; **6** eggs several days old; all enlarged about fourteen times. **7** Peach shoot showing curling and distortion of leaves; **8** peach twig; arrows indicate where eggs are generally laid; both actual size.

twisted and blackened, and often fall. Tender young laterals become twisted and, after the leaves fall, make no more growth; they remain weak and useless, thus depriving the tree of the necessary fruiting wood for next year. The recovery of the fruiting wood may take several years after a severe infestation. Thus the damage in the spring can greatly reduce the current year's crop and jeopardize the next year's crop as well.

If the infestation of young trees is neglected, it can lead to severe injury and distortion of the framework of the trees.

The aphids produce much honeydew which attracts ants and leads to a heavy growth of sooty mould.

Dispersal Winged migrants return from secondary hosts to the peaches in the autumn. On the coast there may be no overwintering eggs, but winged migrants will reach the peaches from secondary hosts in the spring. Young trees from nurseries may introduce overwintering eggs.

Control measures

NATURAL Early fall of peach leaves in the autumn can destroy a large part of the potential population of green peach aphid. Heavy rain at that time can have the same effect. If weather prevents the returning winged males from reaching the peach

Damage by green peach aphid.

trees, the female aphids will lay infertile eggs. Daiber and Schöll (1959) in South Africa have shown that oviposition is always heaviest where trees keep their leaves longest, while Tamaki *et al* (1967) state that early leaf-fall plays the most important role in suppressing aphid populations.

Many natural enemies attack aphid colonies in the spring and the infestation is likely to end soon after the predators appear. The most important predators are ladybirds, especially the transverse ladybird, *Coccinella repanda*, and the common spotted ladybird, *Harmonia conformis*. Syrphid fly larvae and lacewing larvae are also important.

APPLIED In inland areas, spraying in the tree's semi-dormant period, to kill the young aphids when hatching is completed, is the recommended practice. This can often be combined with other insecticidal or fungicidal spraying which is necessary at the time.

Semi-dormant sprays should be applied during mid- and late budswell, before the buds burst. One of the following insecticides may be used: lindane 0.03 per cent-in-oil 1.7 per cent or ethion 0.04 per cent-in-oil 2 per cent.

In the past it has been the practice to apply tar distillate or DNOC-in-oil as dormant sprays to control the overwintering eggs (Woodhill, 1930; Hely, 1933).

If no dormant or semi-dormant sprays have been used or in coastal districts where the aphids do not overwinter as eggs, any of the following materials will usually give good control providing they are applied when the trees have produced some foliage: demeton-S-methyl 0.025 per cent, or dimethoate 0.02 per cent, or thiometon 0.02 per cent, or pirimicarb 0.025 per cent, or methomyl 0.023 per cent. Some green peach aphid populations are now resistant to demeton-S-methyl and some other organophosphorus insecticides. Pirimicarb and methomyl are effective against these aphids. Where early coastal varieties are to be sprayed, dimethoate or methomyl should not be used.

Black peach aphid *Brachycaudus persicae*

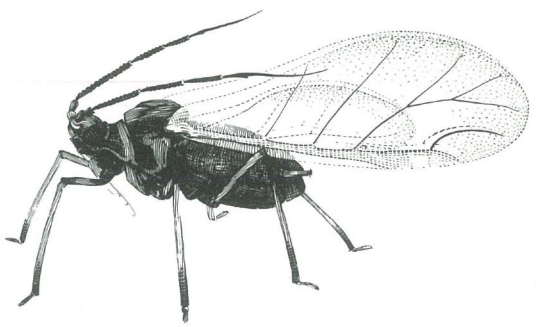
Importance and Distribution This aphid has a world-wide distribution, and may be found in New South Wales wherever peaches are grown. It attacks roots as well as the above-ground parts of plants and can be extremely injurious. Froggatt (1904) gives a detailed account of its habits.

Conditions for Infestation Black peach aphid develops best in mild moist conditions, but it can be a serious pest in hot dry inland areas, although populations can be killed in large numbers by hot dry winds. The underground forms are safe from heat.

Plants attacked Peaches are the main hosts, but nectarines, Japanese plums, almonds, cherries and apricots growing on peach stock may be infested.

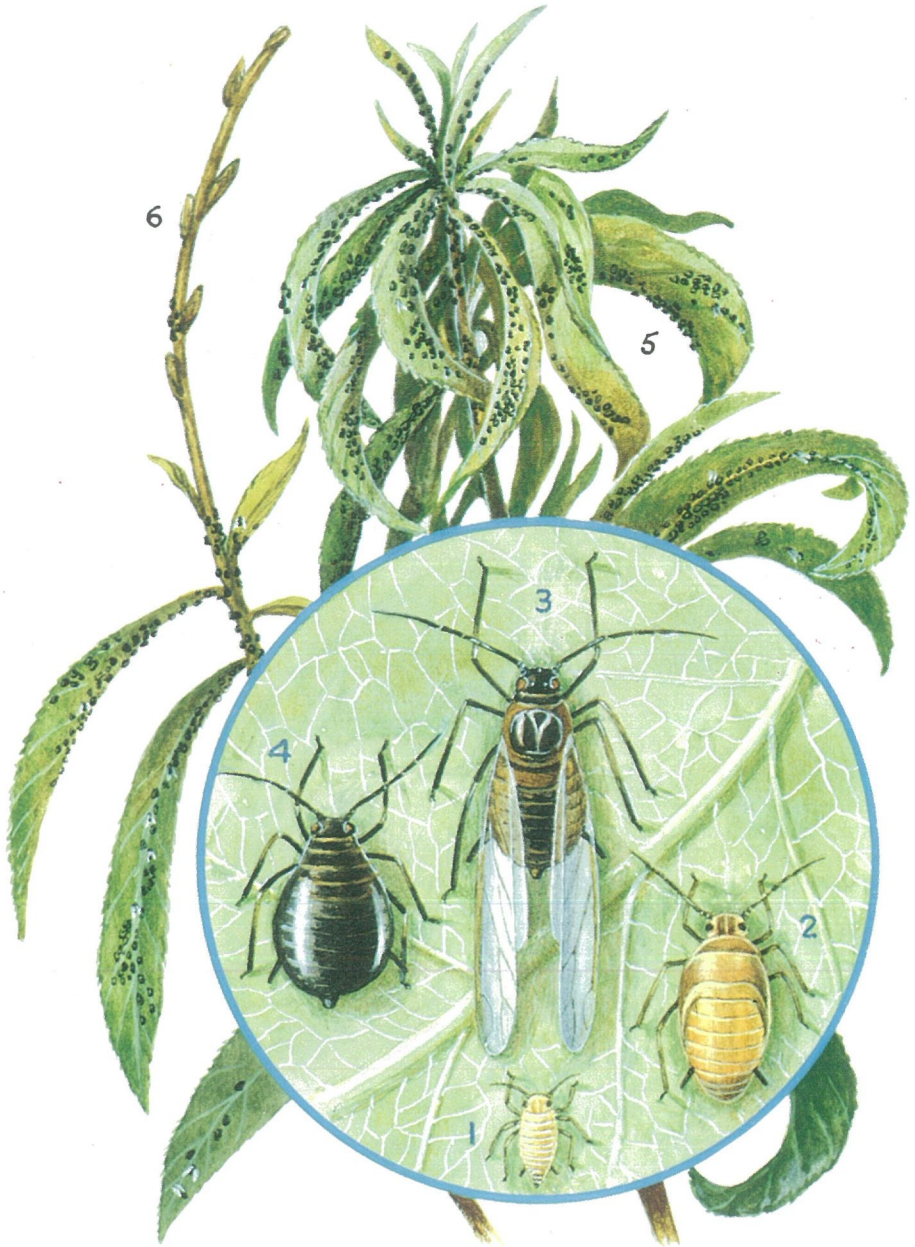
Description and Life History There are winged and wingless female adults which give birth to active young, but no eggs are produced. The adults are glossy black and about 1.5 millimetres long. The nymphs are brown, the youngest being amber.

Wingless forms in all stages of development are found on the roots, usually in colonies at root junctions. Winged forms do not appear on the roots. The population survives the winter low down on the trees in cracks and crevices in the larger limbs and trunk, or below ground on the butts, especially on any sucker growth. With the approach of warmer weather in late winter the aphids become more lively and reproduce more rapidly, giving birth to live young. In spring the aphids move to the blossoms and buds. Wingless adults predominate at all times, but in September and October winged forms usually develop in the colonies.



Black peach aphid – winged female. (Body length 1.5 mm)

Injury These aphids attack some dormant buds, stimulating the buds to develop, and it is typical of black peach aphid attack that individual branches carry open blossoms while those on the rest of the tree are still tightly folded. During this period the aphids feed on the laterals, causing them to become seriously weakened and bent around. The copious production of honeydew is attractive to ants, and becomes heavily infested with sooty mould which covers the limbs and causes a bark-bound condition. If unchecked, the aphids ascend to the tops of the trees and may cause considerable die-back through heavy feeding. In spring, blossoms and buds may be sucked dry. Newly-formed fruits are fed on heavily and fall. An uncommon form of injury, due to late infestation, is typified by slightly-raised reddish roughened areas on the surface of fruits. The aphids



Black peach aphid
Brachycaudus persicae

1 First-stage nymph; **2** nymph of winged adult showing wing buds; **3** winged adult; **4** wingless adult; all enlarged about eighteen times. **5** Peach foliage infested with aphids; **6** peach shoot showing die-back due to aphid attack.

Premature opening of peach buds due to black peach aphid infestation.

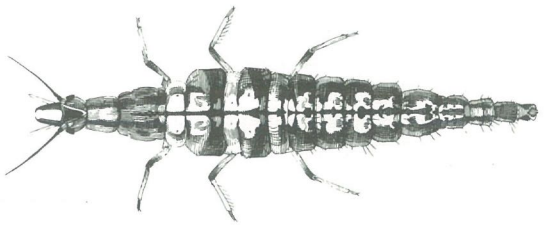
then move to the leaves where they mass, usually on the undersides. The leaves lose colour, wither and drop. Slight leaf-curling, such as is seen in green peach aphid attack, is also evident. It is characteristic of black peach aphid infestations that some parts of a tree are heavily infested while the remainder may be free. On a young tree, however, the infestation is usually general and can seriously harm the framework if it is still in the formative stage.

Dispersal The winged individuals produced in the spring are the main means of dispersal, but it is probable that some wingless forms are transported by the small black ants which are attracted to the honeydew. Nursery trees can be infested; they should have the soil washed from their roots and be examined

carefully before planting out. If aphid infestation is suspected, it is worthwhile dipping young trees – roots and all – in DDT emulsion 0.1 per cent.

Control measures

NATURAL Black peach aphids are eaten by many predators, and parasitized by tiny wasps. The main predators are the common spotted ladybird, *Harmonia conformis*, and the transverse ladybird, *Coccinella repanda*. Lacewing and syrphid fly larvae are also significant. Hot dry weather will seriously deplete their numbers.



Lacewing larva, a predator on aphids. (Length, when fully developed, about 7 mm)

APPLIED Control of black peach aphid was difficult before the advent of DDT. Excellent control was achieved in the Young district (Pasfield, 1946) and the Murrumbidgee Irrigation Area (Wason, 1947) by spraying with DDT 0.1 per cent at the advanced budswell stage in late August. An earlier winter application was not usually necessary as dormant sprays for the control of green peach aphids reduced black peach aphid populations sufficiently until late August. An autumn spray with DDT was sometimes necessary when conditions were ideal for the development of the aphid, but it was usually necessary to spray only the lower half of the infested trees.

Since the development of systemic aphicides it has been possible to attack black peach aphid successfully whenever the trees are in leaf using, for example, demeton-S-methyl 0.025 per cent or pirimicarb 0.025 per cent to ensure good control.

Maldison 0.06 per cent is effective but it must be applied more thoroughly.

At budswell, if the orchard schedule calls for the use of an oil spray against some other pest, ethion 0.04 per cent-in-oil 2 per cent or lindane 0.03 per cent-in-oil 1.7 per cent may be used.

San José scale *Comstockaspis perniciosus*

This insect, which is described more fully on page 107 under Apple Pests, can be a destructive pest of both dessert and canning peaches and of nectarines wherever they grow in New South Wales.

The circular greyish scales are the size of a pinhead, and cluster thickly on the bark of the trunk, limbs and twigs to form scurfy layers. Laterals, twigs, large branches and even young trees can be killed. In fact, the death of some branches on one side of a tree is a typical result of an attack by San José scale. Fruits may also be infested, often with a carmine spot at the point of attachment. Another typical symptom is the exudation of gum droplets on infested wood.

Often most of the scales on older wood seem to be dead, but an examination of the lateral wood, especially where it joins the branch and around the basal buds, shows live bright yellow scale insects when the scale covers are removed. All varieties of peach are susceptible to attack. The very early varieties present a difficult problem as the dormant period available for applying winter sprays is very short; the application of control measures in the growing season is risky due to their high susceptibility to spray injury.

Control measures Control is best established during the dormant season wherever possible and, if the infestation has become heavy, a spray can be applied after the harvest.

For control in varieties with a long dormant period it may be useful to apply two sprays in winter, but two full-strength oil sprays should not be used. Ethion 0.04 per cent-in-oil 2 per cent, or superior dormant oil 3 per cent are the recommended dormant sprays. Lime-sulphur (polysulphides) 1 per cent plus superior dormant oil 1 per cent may also be used. After harvest, carbaryl 0.1 per cent plus oil 1 per cent or ethion 0.06 per cent-in-oil 1 per cent is recommended.

In view of the importance of San José scale and the risk of introducing it to an orchard with young trees from the nursery, such trees should be examined with great care. If any sign of San José scale is seen, they should be dipped in superior dormant oil 3 per cent (not the roots), and then drained in the shade with their tops downwards before planting out as described on page 109 under Apple Pests. The prudent grower will carry out this precautionary treatment as a matter of routine. This simple process may avoid years of expensive and difficult spray treatments.

More details on this pest will be found on page 107 under Apple Pests.

Frosted scale *Eulecanium pruinosum*

Frosted scale, or prune scale, is oval and brown with a light powdery white frosting, and is a common pest on many deciduous and ornamental trees in the inland fruit-growing districts. It can be troublesome in individual peach blocks, but is a more important pest on plums, prunes and apricots. It is one of the soft scales, and produces much sticky honeydew and the consequent development of sooty mould.

Control measures Control is best established by spraying in the dormant season. If this is missed, the pest can be controlled by spraying in the growing season when the scales are immature.

A more detailed treatment of this pest and its control measure is given on page 143 under Plum and Prune Pests.

Peach white scale *Pseudaulacaspis pentagona*

This scale is unimportant in the main peach-growing areas, but attacks peaches in North Coast districts. It attacks wood, leaves and fruit, but is most commonly seen on branches and twigs. In other countries it is recorded on most deciduous fruit trees, yet in New South Wales it is only on the peach.

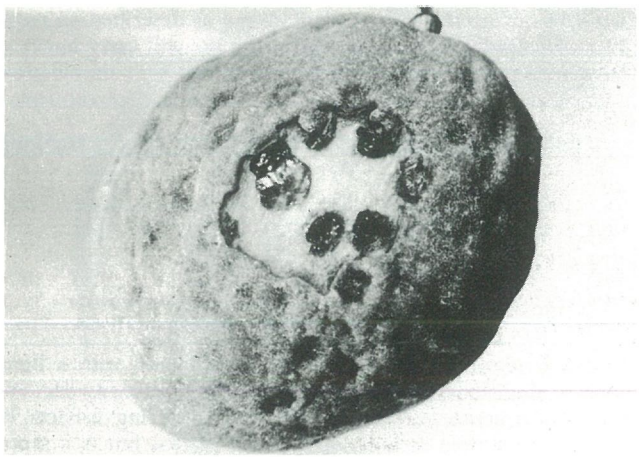
It is a member of the armoured scale group and the females resemble the common white rose scale, but the males are different. The adult female is usually flat and circular, but may be irregular in shape when crowded, about 2 millimetres in

diameter, and white or greyish with a reddish yellow nipple towards one side. The males are smaller and oval, with a slight ridge along the back.

If it should be needed, control can be achieved with any of the methods recommended for San José scale.

Fruit-spotting bug *Amblypelta nitida*

These insects cause damage in spring nearly every year in the Sydney area by feeding on young fruits shortly after setting. Most reports concern home-garden trees, but commercial orchards are involved occasionally. Typical damage caused by feeding is a collapse in parts of the flesh, sometimes involving almost half the side of a fruit. These sunken areas are smooth-sided and may extend as far as the stone. Often there is an exudation of clear gum into the area, and there are always gum pockets inside the fruit when it is cut open. Most of the affected fruit falls when it is small, but some will persist and ripen as useless deformed peaches.



Peach damaged by fruit-spotting bug.

Control measures On peaches the bugs can be controlled, if they are noticed early enough, by spraying with maldison 0.06 per cent soon after fruit-set.

This bug is described in more detail on page 183 under Macadamia Pests.

Green vegetable bug *Nezara viridula*

The adult bugs sometimes migrate from weeds or nearby crops, such as lucerne, to feed on ripening peaches. As a result of their feeding the surface tissues of the peaches become leathery, flecked, and mottled with white dried-out cells. The surface of the injured area is bumpy and uneven. Affected peaches are quite unsuitable for canning.

Control measures As damage is unusual, routine control measures need not normally be used. Should the need arise, spraying with carbaryl 0.1 per cent, or fenthion 0.05 per cent, or maldison 0.075 per cent has generally been effective.

Green vegetable bug is described more fully on page 232 under Bean Pests.

Rutherglen bug *Nysius vinitor*

Adults of these small grey-brown narrow-bodied winged bugs sometimes swarm in huge numbers to peach trees from weed growth which has dried out in summer. Sometimes a swarm settles on the peach leaves and moves off again without causing harm. More often they cluster thickly on the fruits and suck the sap, thus causing extensive injury in a short time. The effect of the feeding depends on the stage of development of the peaches. If the fruit is still green, long thin tendrils of clear gum are produced which hang from the fruits; the fruit fails to mature and remains shrivelled. If the fruit is close to ripening, the affected area is left dried out, leathery, and greenish-coloured in comparison with the normal colour of the rest of the fruit.

Control measures Control may be effected with maldison 0.06 per cent but, as the attack is usually near picking time, a quick-acting short-residual material such as mevinphos 0.05 per cent has been highly effective. Special care is necessary if using this highly toxic insecticide.

Rutherglen bug is dealt with in greater detail on page 163 under Grape Pests.

Coon bug *Oxycarenus arctatus*

These black and white winged bugs are about 3 millimetres long, and sometimes cause alarm by swarming on to the trees from nearby weed hosts. They may completely cover individual

Coon bugs on damaged peach.

peaches, but they usually prefer to assemble in the stem cavity and on the fruit stalk. Occasionally some puncturing and gumming of young fruits are observed, but generally damage is only slight. Control could be achieved by measures recommended for Rutherglen bug above.

Green mirid *Creontiades dilutus*

These pale green narrow-bodied bugs, which are about 6 millimetres long when adult, occasionally cause serious injury to ripening peaches. The results of the green mirid puncturing the fruit are a pitting of the skin, discoloured areas in the flesh, and malformation of the fruit. Long and persistent columns of gummy material exude from the punctures if green fruit is attacked. The bugs are extremely active, and run and fly quickly when disturbed. They do not occur in swarms but in ones and twos on odd fruit. They are not very noticeable so a surprising amount of damage may be done before the problem is recognized. They attack many crops – especially beans, passion vines and potatoes.

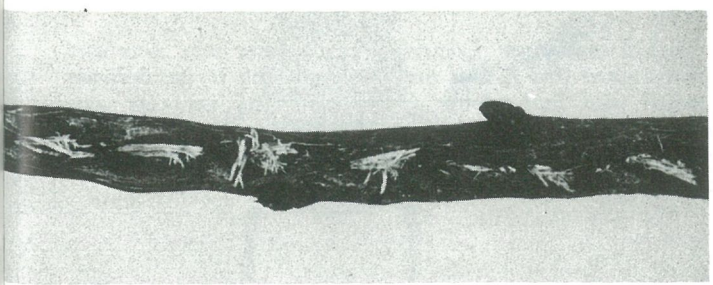
Control measures It might be expected that the effective measures for Rutherglen bug control would be applicable to this pest.

More detail on this pest is given under Bean Pests on page 231.

Cicadas Cicadidae

Several species of cicada have been recorded occasionally causing injury to peach and other fruit trees. They usually do not cause damage when feeding, but do so when laying their eggs. They make slits in the bark of limbs with their knife-like ovipositors, and lay the eggs in the tissue. The narrow white bean-shaped eggs are visible in the slits, and the 'cut-wood' fibres protrude like tufts of wood-wool between the punctures. Some twigs and branches are severely damaged and this will distort the growth and final shape of the tree. The damage is most likely to occur during the latter part of a dry summer and where the fruit trees grow near bushland.

Control measures The problem is difficult to overcome when cicada numbers are very high and their attack is persistent. Spraying with carbaryl 0.1 per cent will kill any cicadas contacted by the spray.



Cicada egg-laying sites in peach stem.

Wingless grasshopper *Phaulacridium vittatum*

These grey-brown hoppers, which damage the foliage and fruits of peaches in some seasons in the tablelands areas, are 12 to 18 millimetres long and have short rudimentary scale-like wings. They can seriously damage young trees, and ripening fruit may be so heavily chewed that only the stone is left. The grasshoppers move in to the orchards from surrounding pasture land when the herbage on which they have developed dries out.

Control measures are described on page 112 under Apple Pests.

Inland katydid *Caedicia simplex*
Citrus katydid *Caedicia strenua*

Importance and Distribution Both the inland katydid, *Caedicia simplex*, and the citrus katydid, *C. strenua*, may damage peaches – the latter species is active on the coast. The inland species is important in the Murrumbidgee Irrigation Area because canning varieties, which ripen relatively slowly, are more susceptible to attack than dessert peaches. The canning varieties remain attractive to the pest insects for a long time when the adult katydids are present. For dessert peaches the time is short between when the fruit is green and when it is harvested, and green fruits do not attract katydids.

Conditions for Infestation Dry conditions with ample irrigation and an absence of hot dry wind suit the katydids best.

Plants attacked Peaches are favoured hosts, but other stone fruits are also attacked. Katydids breeding on citrus trees move to peaches as adults and feed on the ripening fruits. They also feed on some eucalypts. Certain varieties of peach are preferred, and late varieties are not attacked. In a survey in the Murrumbidgee Irrigation Area the percentages of damaged fruits in the total crop were: Selma 22, Phillips Cling 14.5, Golden Queen 10 and Pullars Cling 3 (Wason, 1946). The percentage of damaged fruits was less as the date of maturity of the variety became later in the year.

Description and Life History Both of these katydids are described in detail on page 75 under Citrus Pests.

The young nymphs appear in September–October. There are five nymphal stages; wing buds appear after the third moult. The first adults appear in late November, but they do not generally become abundant until December–January. They live for about two months.

Injury The nymphs feed on low lateral growth and suckers, giving the leaves a lace-like appearance, but do not cause any important damage to the peaches. They subsequently make their way up into the trees where they feed more actively on the foliage.

The adults often damage ripening peach fruit severely. The damage ranges from light nibbling to deep gouging of the fruit. Straight-sided steep wounds up to 2 centimetres wide may be eaten in to the flesh, and there may be more than one wound per

fruit. Each adult katydid may injure many peaches and only a few on each tree can cause considerable losses. Damaged fruit is unsuitable for the choicest canning lines and can be used only after trimming for sliced peaches or jam.

The adults are most active at night and on dull days. Their peculiar clicking mating call is heard in early evening or when cloud obscures the sun. The amount of injury varies from tree to tree – some may have many damaged fruits while there is little harm on other trees close by.

Dispersal Movement of the katydids into, and through, the orchard is almost entirely as winged adults.

Control measures

NATURAL Predatory flies, wasps and bugs probably take some toll of katydids, but birds are thought to be the most important of the natural enemies.

APPLIED Growing season sprays applied to control light-brown apple moth or oriental fruit moth will also give adequate control of katydids. Where special control is needed, maldison 0.075 per cent would probably be efficient. This should be applied early to catch the katydids as nymphs.

ARACHNIDA ACARINA

Bryobia mite *Bryobia rubrioculus*

These small red or brown mites sometimes injure peaches and nectarines, especially in hot dry seasons when the trees have not received adequate moisture. The mites feed on the upper surfaces of leaves causing a bleached stippled effect. A severe attack results in leaf-fall and failure of the fruit to grow to size. Bryobia mite used to be a much more serious peach pest than it is now. Its decline in importance is believed to be due to two factors: modern spray programmes against other pests also check this species; and two-spotted mite has become much more important, and its presence is unfavourable in some way to bryobia mite.

Control measures Control of bryobia mite is achieved by spraying in the dormant period with superior dormant oil 3 per cent.

During the growing season dicofol 0.04 per cent spraying is recommended.

For a more detailed description see page 114 under Apple Pests.

Two-spotted mite *Tetranychus urticae*

This mite is probably the most important and most difficult to control of all peach pests in New South Wales. This is believed to be so for two reasons: the general rejection of sulphur sprays for plant disease control in favour of more modern fungicides; and the use of insecticides, such as DDT, carbaryl and azinphos against moth pests. The latter insecticides have either never been effective against two-spotted mites or the mites have become tolerant or resistant. The insecticides are generally toxic to the enemies of the mites.

The damage by two-spotted mites to peaches resembles that described on page 113 under Apple Pests. The leaves take on a bleached grey appearance and fall early. The fruit is restricted in growth and coloration. Leaves may be partially deformed and have curled edges.

Control measures Mite infestations usually build up in about mid-December, or earlier if the weather is hot and dry. Trees should be watched carefully at that time and sprayed if necessary. Binapacryl 0.05 per cent, or bromopropylate 0.075 per cent, or cyhexatin 0.02 per cent, or fenbutatin oxide 0.02 per cent, or propargite 0.06 per cent spray would be effective. Two treatments within ten days of each other may be needed for effective control of a heavy infestation in summer and a very thorough application is necessary. On large canning peach trees in irrigated orchards, up to 50 litres of spray per tree may be needed to give satisfactory coverage.

Further details of this pest are given on page 112 under Apple Pests.

Peach silver mite *Aculus cornutus*

This tiny worm-like eriophyid mite has been seen on peaches in New South Wales for many years. It turns the leaves a leaden or dull silvery colour late in the season. These tiny narrow mites are about 0.2 millimetre long, taper towards the rear end, and have two pairs of legs near the head. They overwinter under the scales enclosing the buds and move out in the spring to feed on the upper surfaces of new leaves. The silvering first becomes noticeable in about December or January and, by late autumn, all leaves may be affected. This does not seem to cause significant damage as the leaves do not fall prematurely, at least not on irrigated trees. The mites have long been suspected of causing bud shatter or bud shedding, which may reduce the yield of fruit, but for which no other cause has been established. Bud shedding in the Murrumbidgee Irrigation Area was found to be unrelated to the average number of mites per bud (Jones, 1965).

Control measures Control of peach silver mite is usually unwarranted but, if it is necessary, spraying in the dormant period with lime-sulphur (polysulphides) 1 per cent plus superior dormant oil 1 per cent should prove to be adequate.

Almond pests

The area of commercial almond growing in New South Wales totals only about four hectares, mainly in the south west where the summers are hot and dry and water is available for irrigation. Freedom from severe frosts in late winter and early spring is essential as the almond blooms early and can be severely damaged by frost when in full bloom. A dry climate as harvest approaches is also necessary. The coastal and tablelands areas are unsuitable for commercial almond production.

Many almond trees are grown as windbreaks and in farm gardens. In these situations they often receive inadequate attention and insufficient watering, which results in pests, especially bryobia mite, considerably reducing the quantity and quality of the crop. Bryobia mite is the major pest of almonds. Other pests of almonds are listed below. Some comment is made on them on pages 139 to 140, but they are discussed more fully under other crops.

INSECTA LEPIDOPTERA

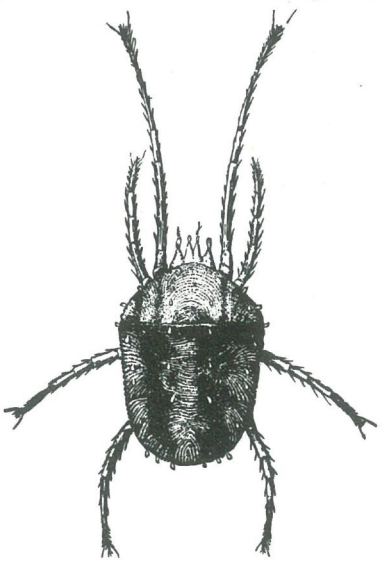
Oriental fruit moth	*Cydia molesta*

HEMIPTERA

Black peach aphid	*Brachycaudus persicae*
Green peach aphid	*Myzus persicae*
Pale cotton stainer	*Dysdercus sidae*
Metallic shield bug	*Scutiphora pedicellata*
San José scale	*Comstockaspis perniciosus*

ARACHNIDA ACARINA

Bryobia mite	*Bryobia rubrioculus*
Two-spotted mite	*Tetranychus urticae*



Bryobia mite is the major pest of almonds.

INSECTA LEPIDOPTERA

Oriental fruit moth *Cydia molesta*

Tip damage to almond trees by larvae is seen occasionally in spring, especially in coastal districts, but oriental fruit moth is not of much significance to almonds. Life history and control are described on page 126 under Peach and Nectarine Pests.

HEMIPTERA

Black peach aphid *Brachycaudus persicae*

Almonds, especially if they are grown on peach stocks, are susceptible to attack by this aphid. Infestation can cause leaf curling, withering of blossoms, curling of the twigs, and dieback. Details of life history and control are given on page 133 under Peach and Nectarine Pests.

Green peach aphid *Myzus persicae*

Almonds can be attacked by this aphid. Life history, injury caused and control are described on page 131 under Peach and Nectarine Pests.

Pale cotton stainer *Dysdercus sidae*
Metallic shield bug *Scutiphora pedicellata*

These bugs have been recorded occasionally attacking almond fruits late in the season, causing the kernels to wither and gum. They migrate in dry weather from other hosts on which they have been breeding. Descriptions and further comments about these bugs are given on page 164 under Grape Pests.

San José scale *Comstockaspis perniciosus*

Almonds are susceptible to infestation by this scale. Life history, injury caused and control are described on page 107 under Apple Pests.

ARACHNIDA ACARINA

Bryobia mite *Bryobia rubrioculus*

In all parts of New South Wales almond trees can be expected to be infested by these mites. Almond varieties differ in their susceptibility to bryobia mite, Peerless being particularly susceptible. After about mid-summer the foliage of infested trees will commonly have a grey-green appearance instead of the natural darker green. As autumn approaches the colour becomes more bleached, leaf-fall may be heavy, and the trees look thin and scraggy. Not only is the crop reduced by the fall of half-developed nuts, but those remaining on the trees are undersized and often empty. Leaf size is affected and trees infested year after year have narrow thin leaves.

Control measures Infestation of almond trees by bryobia mites can be better tolerated if they are watered sufficiently. Control may be achieved by spraying in the winter with superior dormant oil 3 per cent. In the growing season spraying with dicofol 0.04 per cent is recommended.

Further details of bryobia mite life history are given on page 115 under Apple Pests.

Two-spotted mite *Tetranychus urticae*

Almonds are suitable hosts for two-spotted mite, but generally are not attacked much by it. This is because almonds are usually not sprayed for certain other pests, with consequent destruction of natural enemies of this mite. Life history and control of two-spotted mite are discussed on page 113 under Apple Pests.

Plum and prune pests

The important prune-growing industry in New South Wales is centred mainly in the Young district and in the Murrumbidgee Irrigation Area. The main prune varieties are Prune d'Agen and Robe de Sergeant; they are generally worked on Myrobolan plum stock. Almost the whole crop is grown for processing.

Plums are grown for fresh fruit and for jam, but the plantings are not large. European and Japanese varieties are grown at Orange and Young, and on the Northern Tablelands. The main European varieties are President and Angelina, and the most popular of the Japanese varieties are Narrabeen and Santa Rosa. Very early cherry plums grown near Sydney are mostly Gem and Wilson. Early varieties are susceptible to injury by some sprays, particularly maldison and dimethoate. Unwarranted spraying with broad-spectrum pesticides should be avoided on these trees as they may stimulate infestation by pests which were previously either secondary or insignificant.

An account is given on pages 141 to 144 of the pests of plums and prunes listed below.

INSECTA LEPIDOPTERA

Fruit tree borer	*Cryptophasa melanostigma*
Light-brown apple moth	*Epiphyas postvittana*
Codling moth	*Cydia pomonella*

HYMENOPTERA

Pear and cherry slug	*Caliroa cerasi*

DIPTERA

Queensland fruit fly	*Dacus tryoni*

COLEOPTERA

Christmas beetles	*Anoplognathus* spp.

THYSANOPTERA

Plague thrips	*Thrips imaginis*
Greenhouse thrips	*Heliothrips haemorrhoidalis*

HEMIPTERA

San José scale	*Comstockaspis perniciosus*
Frosted scale	*Eulecanium pruinosum*
Grapevine scale	*Parthenolecanium persicae*
Black peach aphid	*Brachycaudus persicae*
Apple leafhopper	*Typhlocyba froggatti*
Fruit-spotting bug	*Amblypelta nitida*

ORTHOPTERA

Wingless grasshopper	*Phaulacridium vittatum*
Inland katydid	*Caedicia simplex*

ARACHNIDA ACARINA

Bryobia mite	*Bryobia rubrioculus*
Two-spotted mite	*Tetranychus urticae*
European red mite	*Panonychus ulmi*

The following may be occasional pests of plums and prune, and are discussed under other crops on the pages listed below.

INSECTA		LEPIDOPTERA
Budworms	*Heliothis* spp.	219
Cup moths	*Doratifera* spp.	145
Leaf case moth	*Hyalarcta huebneri*	26
Oriental fruit moth	*Cydia molesta*	126
		COLEOPTERA
Dried fruit beetles	*Carpophilus* spp.	129
Elephant weevil	*Orthorhinus cylindrirostris*	37
Fruit tree pinhole borer	*Xyleborus saxeseni*	146
Monolepta beetle	*Monolepta australis*	43
		HEMIPTERA
Coon bug	*Oxycarenus arctatus*	136
Green peach aphid	*Myzus persicae*	131
Metallic shield bug	*Scutiphora pedicellata*	164
Rutherglen bug	*Nysius vinitor*	163

INSECTA — LEPIDOPTERA

Fruit tree borer — *Cryptophasa melanostigma*

Larvae of this native moth do a great deal of damage to stone fruit trees by feeding on the bark, sometimes ringbarking the branches and weakening limbs by boring tunnels in the wood. They attack many deciduous fruit, ornamental and shade trees, as well as *Banksia* spp. and black wattles (Froggatt, 1899). The President plum is particularly attractive to them. The trees most commonly infested are plum, apricot, cherry, peach, nectarine and prune, whilst elms, planes and willows are amongst the shade trees which are seriously attacked.

The females lay their eggs on the bark. The small caterpillars, which are yellow, pink and grey with dark brown heads, hatch and burrow into the wood. They tunnel downwards for a few centimetres. Each shelters in its tunnel by day, and comes out at night to feed on the bark surrounding the entrance. The chewed area of bark is covered by thin tough webbing into which are incorporated brown pellets of excrement. In some cases the young larva feeds on wood just under the bark and does not tunnel until the second year. When this happens, the thick bark splits and lifts and the fine sawdust-like frass is pushed out through the cracks. Infestation is usually in forks of branches. The full-fed caterpillars are about 4 centimetres long and dirty white or reddish brown. They pupate in the tunnel, and the emerging moths escape via the tunnel entrance. The adults may have a wing span of up to 6 centimetres across the outspread wings – satiny white forewings and darker hindwings. There is a small black spot near the centre of each forewing. The upper surface of the abdomen is black, with a fringe of orange hairs and a thick tuft at the tip.

Fruit tree borer damage.

Control measures These are best performed in winter during pruning. The sawdust and webbing should be scraped away before a little DDT 1.0 per cent emulsion is squirted into the tunnel and painted around the entrance. Black wattle thickets in the vicinity should be destroyed.

Light-brown apple moth — *Epiphyas postvittana*

These larvae sometimes do considerable damage to prunes and plums by feeding on the surface of the fruits under cover of leaves and amongst clustered fruits. The leaves may be rolled and damaged in a lace-like pattern. The infestation is heaviest low down in the centre of the tree, and may be especially severe on varieties carrying their fruit in clusters.

Control measures Carbaryl 0.1 per cent or fenthion 0.05 per cent would be suitable sprays for control.

Details of the life history may be found on page 96 under Apple Pests.

Codling moth *Cydia pomonella*

In some districts where codling moth is abundant it occasionally infests plums. It is most unlikely that chemical control of this pest on plums would be warranted. Further details are given on page 92 under Apple Pests.

HYMENOPTERA

Pear and cherry slug *Caliroa cerasi*

These slug-like grubs sometimes feed on the foliage of plums. They are discussed more fully on page 148 under Cherry Pests and on page 117 under Pear Pests.

DIPTERA

Queensland fruit fly *Dacus tryoni*

Fruit fly is a serious problem to the growers of plums in the coastal region, and in some other districts when the fly becomes numerous. Infestation can be expected in the late-ripening varieties like Santa Rosa, Wickson and Narrabeen. Blood plums are notoriously susceptible to fly attack. Early-maturing varieties, such as Wilson, Patterson Early and Santa Rosa, often escape serious attack. Even early varieties in some seasons may be infested while still hard and green; the maggots channel through firm flesh and no mushy breakdown occurs. This type of injury results from an attack on the fruit in early spring by overwintering flies, when the plums have the same role as loquats in helping to rear the fly population until summer fruits are available. Generally the infestation of unripe plums affects only a small part of the crop, and there is likely to be a lull of a few weeks before the coloured fruit becomes susceptible. The early attack is evident from beads of gum exuding from the green fruits.

Control measures Recommendations for controlling fruit fly on plums are generally similar to those given on page 129 under Peach and Nectarine Pests. Early plums, like early peaches, will probably be injured by dimethoate.

COLEOPTERA

Christmas beetles *Anoplognathus* spp.

These large scarab beetles are about 2.5 centimetres long. In tablelands districts, they sometimes swarm on to plums in mid-summer and heavily attack leaves, twigs and fruit. The leaves and twigs are chewed in a ragged fashion, especially in the tops of the trees, while the fruit may be eaten down to the stone. European plums seem to be particularly susceptible. On the coast, the species *Repsimus manicatus* Swartz also seems to prefer plums to other fruit trees.

Control measures The invasions are unpredictable. If a swarm can be seen before it has done much damage, it may be dealt with by spraying with a quick-acting insecticide that can be used safely even shortly before harvest, such as carbaryl.

THYSANOPTERA

Plague thrips *Thrips imaginis*

Blossom infestation by plague thrips is common on plums and prunes, but the resulting reduction in fruit set does not seem to be important. Some of the egg-laying in flower stalks does cause the fall of blossoms or very young fruit. The most noticeable result of plague thrips infestation on the trees is the 'shot-hole' effect on young leaves which follows egg-laying in the tender tissues. When the tissue dies, small areas fall out leaving irregularly-shaped holes in the expanding leaves. This does not warrant any special control treatment.

Greenhouse thrips *Heliothrips haemorrhoidalis*

Coastal plum trees in shaded sheltered situations are sometimes heavily infested in late summer by these thrips. It causes leaves to turn a dirty brownish grey, with spots of tarry black excrement, and wither and fall. As the crop has usually been harvested by the time the attack develops, it is unlikely that control measures would be worthwhile. Due to the activities of a tiny wasp parasite, a heavy infestation of greenhouse thrips in the autumn is usually followed by comparative freedom from the pest during the next season.

More details will be found on page 43 under Citrus Pests.

San José scale *Comstockaspis perniciosus*

Some varieties of plums and prunes, such as Japanese plums and Prune d'Agen, are very susceptible to this scale and severely damaged by it. In an inter-planted block at Leeton, a survey showed that there were less than two scales per lateral on Robe de Sergeant prunes while there were over 26 on the more susceptible Prune d'Agen.

San José scale infestation kills the branches and twigs of plums, leaving the dried-out leaves hanging in a characteristic way. This scale resembles wet wood ashes when on the bark of plums and prunes.

Control measures Those recommended on page 135 under Peach and Nectarine Pests are also appropriate to plums and prunes. It is important that winter oil sprays should not be applied later than the early white stage, or bud injury may result.

Frosted scale *Eulecanium pruinosum*

This introduced pest was first recorded in New South Wales at Bathurst in 1928. It is a large brown scale which is distinguished in its adult stage by a covering of powdery white wax, giving it a frosted appearance. It is often abundant on plums and prunes in inland areas, and commonly attacks apricots, peaches and cherries, and ornamental *Prunus* species. The scales overwinter as nymphs which lie along the laterals and fruiting spurs, generally on the lower surfaces. They are then light brown, slightly convex, oval and soft-bodied. In late winter they develop rapidly, and reach adulthood in late September and October. They are then dark brown, about 5 millimetres long and 3 millimetres wide, and the parchment-like scale cover is sprinkled with fine white powdery wax and has a few fine white hairs.

The new adult female starts to produce eggs that accumulate under her body. They are pure white and oval, and begin to hatch in late November. The crawlers are straw-coloured, and they settle on the lower surfaces of leaves beside veins. They start to feed and produce sticky honeydew in fine droplets. The honeydew soon becomes obvious on leaves and fruit and collects dust, but there is no observable direct effect of their feeding on the leaves. The first-stage scales stay on the leaves until autumn with little change. Then they moult and migrate back to the twigs. The sooty mould that follows honeydew production can seriously down-grade fruit and, by blocking out light for photosynthesis, interfere with normal sizing.

Control measures Control is best achieved by spraying in the dormant period with superior dormant oil 3 per cent or ethion 0.04 per cent-in-oil 2 per cent. This should be done very thoroughly to contact the lower surfaces of laterals, and it should be done before the early white stage. If this winter spraying should be missed, control can be effected by spraying in the post-harvest period with maldison 0.1 per cent plus oil 1 per cent, but maldison should not be used on early coastal varieties.

Frosted scale on plum twig.

Grapevine scale *Parthenolecanium persicae*

This species is similar in appearance to the frosted scale except that it does not have the frosting. The adult grapevine scales are also slightly longer and less convex than the frosted scale. Grapevine scale is common on plum trees in the coastal region, and has been seen to become numerous after the application of DDT. It is normally kept down to a harmless level by wasp parasites. If chemical control should become necessary, the methods recommended for frosted scale should be used.

This pest is described on page 161 under Grape Pests.

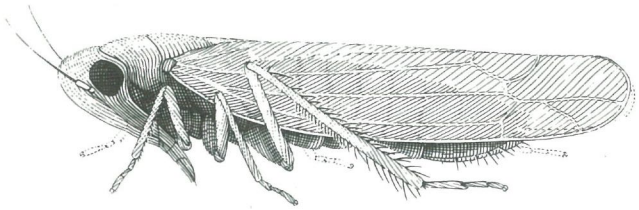
Black peach aphid *Brachycaudus persicae*

This aphid infests Narrabeen plums in much the same way that it does peaches. Control may be necessary in spring or autumn and the methods are described on page 133 under Peach and Nectarine Pests.

Apple leafhopper *Typhlocyba froggatti*

These small active pale green or yellowish, winged or wingless, leafhoppers are sometimes seen infesting prunes at Young, causing mottled leaf injury and depositing speckled excrement. Injury is mostly seen on young trees and has not been important. Spraying with DDT 0.1 per cent is an effective control.

Details of life history are given on page 111 under Apple Pests.



Apple leafhopper. (Length about 4 mm)

Fruit-spotting bug *Amblypelta nitida*

Almost every year fruit-spotting bugs damage newly-set plum fruits in Sydney suburban gardens, and the injury sometimes appears also in commercial plantings in the district. Typical damage shows up as sunken irregularly-shaped areas in the fruit, with pockets of yellow gum underneath. Many of the fruits fall long before they approach maturity. Control measures are described on page 136 under Peach and Nectarine Pests.

ORTHOPTERA

Wingless grasshopper *Phaulacridium vittatum*
Inland katydid *Caedicia simplex*

These pests may attack plums. They are described on page 111 under Apple Pests and on page 137 under Peach and Nectarine Pests.

ARACHNIDA ACARINA

Bryobia mite *Bryobia rubrioculus*

This mite is to be found on prunes and plums almost wherever they are grown. It is probably better known on prunes as they are grown in drier areas.

Damage takes the form of grey speckling of the leaves, often in the spring and sometimes in the autumn as well. This mite leaves no webbing. It was an important pest before the introduction of broad-spectrum sprays in the mid-1940s which resulted in great increases in two-spotted mite populations with the consequent displacement of bryobia mite as an important pest.

Bryobia mite and its control measures are discussed on page 114 under Apple Pests. If a winter treatment of oil is to be applied, it should not be delayed beyond the early white stage.

Two-spotted mite *Tetranychus urticae*

In recent years this pest has taken the place of bryobia mite in many orchards, especially on prunes. This situation has followed the use of broad-spectrum insecticides, either applied directly to the prunes or received accidentally as drift from apple and peach blocks. The build-up of two-spotted mite is heralded by a light speckling of the leaves, usually in the lower parts of the trees. The leaves finally turn grey and their undersides become covered with webbing that holds dust. The infested trees have a drab look. Leaf-fall follows and the trees may be partly defoliated by the end of summer; fruit size and quality are adversely affected.

Control measures Spraying with binapacryl 0.05 per cent, or bromopropylate 0.075 per cent, or cyhexatin 0.02 per cent is effective in controlling this pest.

This pest and its control are discussed more fully on page 112 under Apple Pests.

European red mite *Panonychus ulmi*

This pest was first recorded in New South Wales at Orange in the mid-1950s, but has never caused important damage there. It is described in some detail on page 115 under Apple Pests.

Apricot pests

Apricots are grown commercially in New South Wales, mainly in the Murrumbidgee Irrigation Area where the crop is used for canning or jam making, with a significant quantity sold as fresh fruit. Small areas are also grown at Kurrajong for the early fresh-fruit market.

The apricot is not normally subject to serious damage by pests, partly because its fruit matures so quickly. No standard spray programme is necessary, so there has been no upset in the predator–pest relationship as with other deciduous fruits. Rather more pests are seen on home-garden apricots than in commercial orchards. Early varieties are susceptible to injury by some sprays, particularly dimethoate and maldison.

An account is given on pages 145 to 147 of the pests of apricots listed below.

INSECTA		LEPIDOPTERA
Light-brown apple moth	*Epiphyas postvittana*	
Cup moths	*Doratifera* spp.	
		COLEOPTERA
Dried fruit beetles	*Carpophilus* spp.	
Fruit tree pinhole borer	*Xyleborus saxeseni*	
		HEMIPTERA
San José scale	*Comstockaspis perniciosus*	
Frosted scale	*Eulecanium pruinosum*	
Rutherglen bug	*Nysius vinitor*	

The following pests may be found occasionally on apricots and are discussed under other crops on the pages listed below.

INSECTA		LEPIDOPTERA
Budworms	*Heliothis* spp.	219
Fruit tree borer	*Cryptophasa melanostigma*	141
Leaf case moth	*Hyalarcta huebneri*	26
Oriental fruit moth	*Cydia molesta*	126
Painted apple moth	*Teia anartoides*	99
		DIPTERA
Queensland fruit fly	*Dacus tryoni*	31
		COLEOPTERA
Apple weevil	*Otiorhynchus cribricollis*	40
Elephant weevil	*Orthorhinus cylindrirostris*	37
Fuller's rose weevil	*Asynonychus cervinus*	36
Vine weevil	*Orthorhinus klugi*	159
		HEMIPTERA
Black peach aphid	*Brachycaudus persicae*	133
Cicadas	Cicadidae	137
Coon bug	*Oxycarenus arctatus*	136
Green vegetable bug	*Nezara viridula*	232
Metallic shield bug	*Scutiphora pedicellata*	164
		ORTHOPTERA
Inland katydid	*Caedicia simplex*	137
ARACHNIDA		ACARINA
Bryobia mite	*Bryobia rubrioculus*	114
Two-spotted mite	*Tetranychus urticae*	236

INSECTA — LEPIDOPTERA

Light-brown apple moth — *Epiphyas postvittana*

In some seasons the larvae of this moth, having bred on the herbage of the orchard floor, migrate into the trees when hot dry spring weather dries off their food plants. The half-grown caterpillars can injure fruit and foliage, operating mainly in the lower half of the centre of the tree. Leaf-rolling and webbing, some chewing of leaves, and surface grazing of the fruit are all characteristic. There is a good deal of gum production from the fruits.

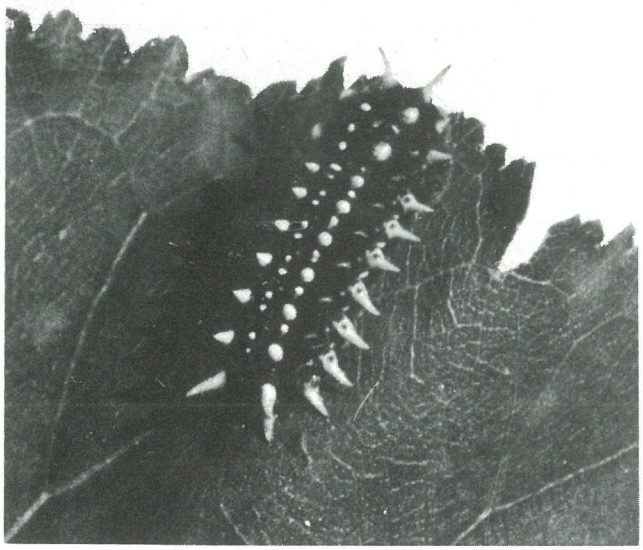
Control measures Azinphos-methyl 0.05 per cent or carbaryl 0.1 per cent spray is effective in controlling this pest.

Details of life history are given on page 96 under Apple Pests.

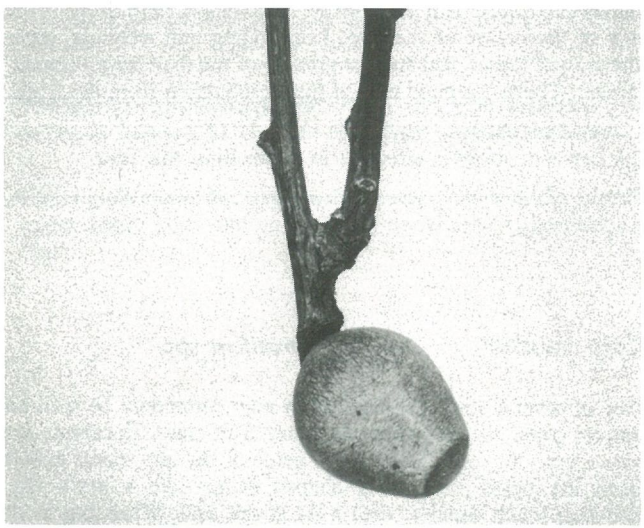
Cup moths — *Doratifera* spp.

One of several species of cup moth may commonly be seen on apricot trees, but not often on other fruit trees. Eucalypts are native hosts of these moths. The name of the cup moths comes from the pupal case being shaped rather like a hen's egg, although much smaller, with a lid at one end. When the moth emerges, the lid is removed to leave a neat cup-like structure on the twig.

The larva is brightly coloured in black and yellow or grey, brown, mauve and pink. It is up to 2.5 centimetres in length, stout and square-ended, with raised areas at the front and rear ends of the back from which project clusters of stinging hairs. There is a row of tapered protuberances around the lower margins of the body. The moths are thick-set and sturdy, generally brown, and have a wingspan of approximately 2.5 centimetres. The eggs are laid on the bark. The larvae feed on the leaf surfaces, usually in strips, but as they get older they may consume whole leaves, except for the main veins. A few grubs are not noticed in the tree, nor is the damage they do. The grower may first become aware of cup moths when he sees the smooth, grey fibrous pupal cases attached to twigs at pruning. Special control of cup moth larvae is seldom worthwhile. If a gross infestation occurs in the spring, it could be controlled by spraying with carbaryl 0.1 per cent.



Cup moth larva.



Cup moth cocoon on twig.

Dried fruit beetles *Carpophilus* spp.

These beetles do slight damage to apricots by eating the fruits through the stem cavity or at the suture lines. They are much more important in the indirect role of transferring the spores of brown rot fungus from old mummified fruits to the early blossoming apricot, and thus initiating the blossom blight stage of the disease (Kable, 1969b). It is in apricots that populations of dried fruit beetle can build up and later migrate to ripening peaches. It is important, where apricots and peaches are grown near each other, to practise careful orchard hygiene right through the apricot season. It is also necessary to arrange for the proper disposal of windfalls and cull fruit during harvest.

Further details of the life history and control of dried fruit beetles are given on page 129 under Peach and Nectarine Pests.

Fruit tree pinhole borer *Xyleborus saxeseni*

These small cylindrical beetles are 2.5 millimetres long, and lay eggs in bark. The larvae make galleries in the wood which are lined with black fungal threads. The emerging beetles make pinholes in the bark. These beetles are usually reddish brown or black, with the prothorax overhanging the head. The larvae mine just under the bark, feeding on the cambium and adjacent tissues, and leaving characteristic engravings on both the inside of the bark and on the wood. Fine sawdust-like excrement is pushed out of the galleries and accumulates in small piles on the bark. These beetles only thrive on trees that are already unhealthy. Apricots and plums are more susceptible than other trees, but special control for them appears not to be worthwhile. Pinhole borers in New South Wales were discussed by Gurney (1915) and in Queensland by Caldwell (1946).

Fruit tree pinhole borer emergence holes.

HEMIPTERA

San José scale *Comstockaspis perniciosus*

Occasionally, and unusually, apricots may be heavily infested by this scale. Life history and control are described on page 107 under Apple Pests and on page 135 under Peach and Nectarine Pests, except that lime-sulphur is not used on apricots.

Many specimens which are suspected as being San José scale on apricot are simply the lenticels of young wood. The lenticels are circular, grey and often surrounded by red tissue, and do in fact look like the scale. However, these lenticel spots show up most clearly on trees in their best vigour. If San José scale established an infestation, the tree would soon be in ill-health.

Frosted scale *Eulecanium pruinosum*

This scale occurs fairly commonly on apricots. If not controlled, it can cause problems as the copious honeydew dirties the fruit and detracts from its appearance.

The crawlers begin to hatch in late November, settle on the undersides of leaves, and quickly produce much honeydew.

A more detailed description and recommended control measures are given on page 143 under Plum and Prune Pests.

Rutherglen bug *Nysius vinitor*

In seasons when swarming by the Rutherglen bug occurs, the apricot is usually the first fruit tree to be attacked. Conditions leading to bug migrations coincide with the ripening of apricots. A crop can quickly be destroyed by the bugs as the fruit is sucked of its juices and becomes leathery and limp, as well as being dirtied by excrement. Control measures are described on page 136 under Peach and Nectarine Pests.

Cherry pests

In New South Wales commercial cherries are mostly grown in the Orange and Young districts. There are also small plantings in the New England district and on the Southern Tablelands. Few cherry trees are grown as home-garden trees or in farm gardens. Almost all the varieties grown are sweet cherries and most of the crop is sold as fresh fruit, although some of it is processed for the confectionery trade. Harvesting begins at the end of October and lasts until early January. The early white to early blossom period is from mid- to late September, with full bloom in late September and early October, and shuck-fall in late October to early November.

An account is given on pages 148 to 151 of the pests of cherries listed below.

INSECTA

HYMENOPTERA

Pear and cherry slug	*Caliroa cerasi*

COLEOPTERA

Soldier beetle	*Chauliognathus lugubris*

HEMIPTERA

Cherry aphid	*Myzus cerasi*

The following pests may also be found on cherries, some being important from time to time, and are discussed as pests of other crops on the pages listed below.

INSECTA

LEPIDOPTERA

Budworms	*Heliothis* spp.	219
Fruit tree borer	*Cryptophasa melanostigma*	141
Leaf case moth	*Hyalarcta huebneri*	26
Light-brown apple moth	*Epiphyas postvittana*	96
Oriental fruit moth	*Cydia molesta*	126
Painted apple moth	*Teia anartoides*	99

DIPTERA

Queensland fruit fly	*Dacus tryoni*	31

COLEOPTERA

Christmas beetles	*Anoplognathus* spp.	142
Pumpkin beetle	*Aulacophora hilaris*	261

THYSANOPTERA

Plague thrips	*Thrips imaginis*	102

	HEMIPTERA	
Black peach aphid	*Brachycaudus persicae*	133
Cicadas	Cicadidae	137
Frosted scale	*Eulecanium pruinosum*	143
San José scale	*Comstockaspis perniciosus*	107

	ORTHOPTERA	
Wingless grasshopper	*Phaulacridium vittatum*	111

ARACHNIDA	ACARINA	
Bryobia mite	*Bryobia rubrioculus*	114
Two-spotted mite	*Tetranychus urticae*	236

INSECTA HYMENOPTERA

Pear and cherry slug *Caliroa cerasi*

Importance and Distribution This world-wide pest appears each year in cherry-growing districts and usually requires treatment. If the larvae are numerous and are not treated, the trees look as if they have been scorched by fire.

Conditions for Infestation Pear and cherry slug is normally more successful in the cooler higher districts, but in a cool moist spring it may also be found in areas which are usually hotter and drier.

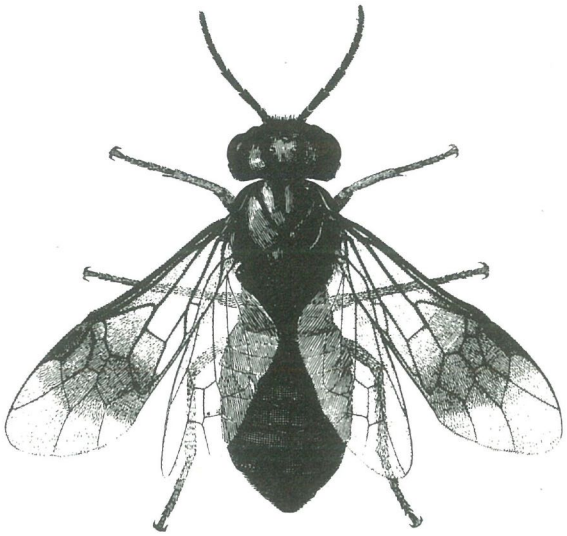
Plants attacked Cherries are the main hosts of pear and cherry slug, but pears, apples, quinces and plums can also be attacked. Ornamental plants, especially hawthorn, are sometimes grossly infested.

Description and Life History The larvae are slug-like, olive green to black, up to 12 millimetres long, and become covered with a greenish slime. They feed on the surface of leaves.

In late autumn the larva makes a small earthen cell in the soil and remains quiescent within it. In spring the hibernating larva forms a pupa, and the adults emerge during October. The adults are glossy black 'sawfly' wasps about 8 millimetres long, with two pairs of transparent wings. The female has a saw-like ovipositor for slitting the leaf tissue to deposit small oval flattened eggs under the epidermis. The eggs hatch in about two weeks as tiny white grubs tapering towards the tail end.

There are two broods in the year. The first larvae appear on the trees in November and December, and they develop into adults that emerge during December and January. These adults produce the second-brood larvae which are normally numerous and capable of stripping trees. Some of these larvae stay on the trees until the weather becomes cold when they enter the soil and make their overwintering cells.

Injury The larvae feed mostly on the upper surfaces of leaves that become curled, shrivelled and 'scorched'. Heavy attack may reduce leaves to a network of veins.



Pear and cherry slug adult. (Length about 8 mm)

Pear and cherry slug larva on damaged leaf.

Pear and cherry slug damage.

Dispersal Dispersal is mainly by the flight of adults. As there are no pear and cherry slugs on the trees in winter, nursery trees are most unlikely to introduce the pest.

Control measures

NATURAL There appear to be no parasites in New South Wales which attack the pear and cherry slug specifically. Parasites introduced in 1928 and 1931 failed to become established (Wilson, 1960).

APPLIED Control of pear and cherry slug can be achieved by spraying in mid-November with maldison 0.06 per cent. Dimeton-S-methyl, used against cherry aphid in November, will also control pear and cherry slug.

HEMIPTERA

Cherry aphid *Myzus cerasi*

Importance and Distribution Cherry aphid, an introduced pest, can be found wherever cherries are grown in New South Wales. An infestation may be spread irregularly through an orchard – some trees being heavily attacked and others left unharmed. However, in exceptional years nearly all the trees are damaged.

Conditions for Infestation Mild moist weather in spring and early summer leads to a rapid increase in aphid numbers by delaying the hardening-off of cherry foliage and by retarding the breeding of predators.

Plants attacked Only fruiting and ornamental cherries are regarded as hosts to this species of aphid, but Zeck (1936) bred *Myzus cerasi* on watercress and later discovered a small natural infestation of the plant at Orange.

Description and Life History This aphid is black when mature but brown in the younger stages. It produces winged males and wingless egg-laying females in the late autumn. After mating, the overwintering black eggs are laid and stuck around the bases of buds. They begin to hatch early in August and continue into September, the young developing slowly at that time, to be mature when the buds burst. The females are wingless, 2.5 millimetres long and viviparous, and can produce young themselves as soon as nine days after birth. Late in the spring winged viviparous females appear, and they may spread the infestation within a tree or through an orchard. As the cherry growth hardens-off, aphid numbers decrease markedly. The important part of the population can then be found only on sucker growth around the margins of the orchard.

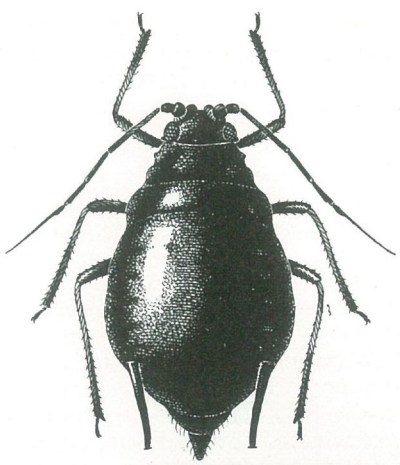
As well as overwintering as eggs on the trees, some small colonies may be able to survive and breed slowly even through periods of frost and snow. Their presence is usually indicated by 'pinking' and swelling of the buds on the infested twigs. During winter when aphids are feeding on dormant trees,

COLEOPTERA

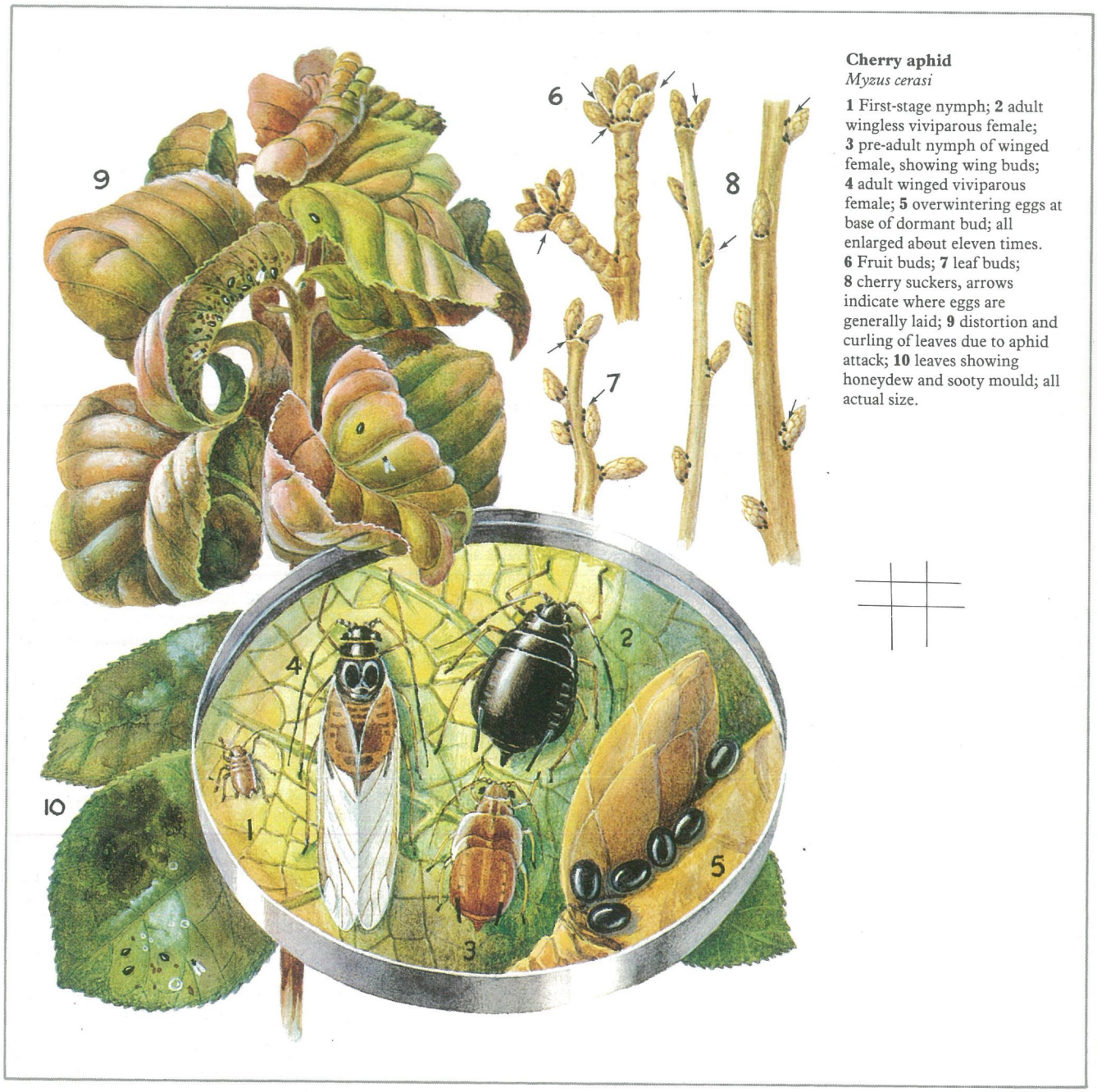
Soldier beetle *Chauliognathus lugubris*

Soldier beetles, which are commonly found on bush flowers in late spring and summer, sometimes settle together in swarms on garden plants and blossoms of fruit trees, especially apples. They have rarely been observed to feed, and normally do no damage beyond weighing down garden plants by sheer numbers or, possibly, by interfering with pollination of blossoms by bees. However, they have been observed to cluster on ripening cherries, and nibble holes in the lower ends of the fruits.

The adult beetles are about 13 millimetres long, narrow and soft, with a black head, a yellow band across the prothorax, bronze-green or olive green wings and a yellow abdomen. The immature stages and the life cycle are not known.



Cherry aphid – wingless viviparous female. (Length 2.5 mm)



Cherry aphid
Myzus cerasi

1 First-stage nymph; **2** adult wingless viviparous female; **3** pre-adult nymph of winged female, showing wing buds; **4** adult winged viviparous female; **5** overwintering eggs at base of dormant bud; all enlarged about eleven times. **6** Fruit buds; **7** leaf buds; **8** cherry suckers, arrows indicate where eggs are generally laid; **9** distortion and curling of leaves due to aphid attack; **10** leaves showing honeydew and sooty mould; all actual size.

premature growth of infested parts occurs leading to development of leaves and, in some cases, to blossoming with subsequent die-back.

Injury The main damage is done by the large numbers that breed up in the spring. Young terminal growth is attacked, the leaves and twigs becoming curled, yellow and covered with honeydew and sooty mould. Infestation is usually most severe on young trees – every leaf cluster may be involved. The fruit may be unmarketable. Premature opening of buds in winter, following an infestation at that time, may severely affect later cropping. If trees are allowed to remain heavily infested for several years, they may die or become unproductive.

Dispersal Movement within the orchard is accomplished by the flight of winged aphids. Introduction of the pest to an orchard is most likely to be due to eggs on young trees, and measures should be taken to prevent this by treating the trees before planting.

Control measures

NATURAL Ladybirds, such as common spotted ladybird, *Harmonia conformis*, and transverse ladybird, *Coccinella repanda*, and their larvae prey heavily on cherry aphids. Syrphid fly and lacewing larvae also do good work in eating many aphids.

APPLIED Development of control measures by spraying in winter or early spring has been described by Zeck (1936, 1937)

and Lloyd (1950). It is now recommended that control measures be adopted in the growing season either when the infestation first appears, or as a routine spray early in November in orchards with a consistent history of infestation. The advantage of this procedure is that spraying will be done only when there is a real problem. The use of systemic insecticides in the spring gives an excellent kill, and coverage does not have to be complete. These insecticides do not have a very damaging effect on the aphid's natural enemies at the time when those predators are being most useful. The insecticides currently recommended are demeton-S-methyl 0.025 per cent, or thiometon 0.025 per cent. If a treatment is needed close to harvest, mevinphos 0.014 per cent can be used but it is very toxic to users so special precautions are necessary when applying it.

Cherry aphid damage.

References

Allen, H. W. (1958). The Oriental Fruit Moth. *Agriculture Information Bulletin No. 182.* United States Department of Agriculture.

Allman, S. L. (1948). Skin blemish of nectarines caused by plague thrips. *Agricultural Gazette of New South Wales* **59**: 423–6.

Anon (1966). Dried fruit beetles, *Carpophilus* spp. *Entomology Branch Annual Report, New South Wales Department of Agriculture*, p.20.

Caldwell, N. E. H. (1946). Pin-hole borers in deciduous fruit trees. *Queensland Agricultural Journal* **63**: 282–3.

Daiber, C. C. and Scholl, S. E. (1959). Further notes on the overwintering of the green peach aphid, *Myzus persicae* (Sulzer), in South Africa. *Journal of the Entomological Society of Southern Africa* **22**: 494–520.

Froggatt, W. W. (1899). Entomological notes for 1898. *Agricultural Gazette of New South Wales* **10**: 873–9.

Froggatt, W. W. (1904). Experimental work with the peach aphis (*Aphis persicae-niger* Sm.). *Agricultural Gazette of New South Wales* **15**: 603–12.

Froggatt, W. W. (1914). The peach tip moth. *Agricultural Gazette of New South Wales* **25**: 413–4.

Gaven, M. J. (1964). *Carpophilus* beetles as a pest of peaches. *Journal of the Entomological Society of Australia (N.S.W.)* **1**: 59–62.

Gurney, W. B. (1915). Some insect pests of apples and pears. *Agricultural Gazette of New South Wales* **26**: 303–12.

Helson, G. A. H. (1939). The Oriental peach moth (*Cydia molesta* Busck). Investigations in the Goulburn Valley, Victoria. Progress report for Seasons 1935–38. *C.S.I.R. (Australia) Pamphlet No. 88*, p.18.

Hely, P. C. (1933). Control of the green peach aphid on the Murrumbidgee Irrigation Area. *Agricultural Gazette of New South Wales* **44**: 751–8.

Jones, E. L. (1965). The silver leaf mite and bud shed of peaches. *Australian Journal of Science* **28**: 27.

Jones, E. L. (1967). The oriental fruit moth. *Agricultural Gazette of New South Wales* **78**: 728–9.

Kable, P. F. (1969a). Brown rot of stone fruits on the Murrumbidgee Irrigation Areas. I. Aetiology of the disease in canning peaches. *Australian Journal of Agricultural Research* **20**: 301–16.

Kable, P. F. (1969b). Brown rot of stone fruits on the Murrumbidgee Irrigation Areas. II. Aetiology of the disease in Trevatt apricot trees. *Australian Journal of Agricultural Research* **20**: 317–23.

Lindgren, D. L. and Vincent, L. E. (1953). Nitidulid beetles infesting California dates. *Hilgardia* **22**: 97–118.

Lloyd, N. C. (1950). The cherry aphid (*Myzus cerasi* Fab.) in the Orange district. *Agricultural Gazette of New South Wales* **61**: 83–6, 149–52.

Pasfield, G. (1946). Control of black peach aphids (*Anuraphis persicae-niger*) by the use of DDT. *Agricultural Gazette of New South Wales* **57**: 201–4.

Tamaki, G., Landis, B. J. and Weeks, R. E. (1967). Autumn populations of green peach aphid on peach trees and the role of syrphid flies in their control. *Journal of Economic Entomology* **60**: 433–6.

Wason, E. J. (1946). The inland green tree-hopper (*Caedicia simplex* Walk.). An important pest of canning peaches. *Agricultural Gazette of New South Wales* **57**: 521–4.

Wason, E. J. (1947). The black peach aphid (*Anuraphis persicae-niger*) in the Murrumbidgee Irrigation Area. *Agricultural Gazette of New South Wales* **58**: 525–9.

Wilson, F. (1960). *A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea.* Technical Communication No. 1, Commonwealth Institute of Biological Control, Ottawa, Canada. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks., England. 102pp.

Woodhill, A. R. (1930). The green peach aphid (*Myzus persicae*). Progress report on spraying experiments. *Agricultural Gazette of New South Wales* **41**: 311–4.

Zeck, E. H. (1928). The green peach aphid, *Myzus persicae* (Sulzer). *Agricultural Gazette of New South Wales* **39**: 147–54.

Zeck, E. H. (1936). The cherry aphid (*Myzus cerasi* Fab.). *Agricultural Gazette of New South Wales* **47**: 255–8.

Zeck, E. H. (1937). The cherry aphid (*Myzus cerasi* Fab.). *Agricultural Gazette of New South Wales* **48**: 216–8.

GRAPE

Grape pests

Grape culture began with the first settlement in New South Wales. Governor Phillip reported 4 acres under vines in 1791 near Parramatta. Vines were soon planted in the Camden district, and in the 1830s important plantings were made in the Hunter Valley. With the development of irrigation along the Murrumbidgee and Murray Rivers there was a great increase in the area under grapevines for the three main uses – table grapes, wine-making and dried fruits.

Climate defines the regions suitable for profitable grape production; this is essentially a dry climate crop, which is rarely grown where the average rainfall exceeds 750 millimetres per year. In districts with higher rainfall, especially with high summer humidity, the cost of controlling the fungus diseases black spot and downy mildew is prohibitive.

Insect pests of grapes in New South Wales were amongst the first to receive official attention. The dreaded phylloxera was the first insect to which government-directed eradication measures were applied. Resistant stocks (which had already been proved in the re-establishment of grape-growing in France after the phylloxera disaster) were used, and quarantine measures to keep certain districts clean were successful. Thus grape production became and has remained one of the most important fruit industries in New South Wales.

An account is given on pages 155 to 168 of the pests of grapes listed below.

ARTHROPODA

INSECTA

LEPIDOPTERA

Grapevine moth	*Phalaenoides glycinae* Lewin
Grapevine hawk moth	*Hippotion celerio* (Linnaeus)
Vine hawk moth	*Theretra oldenlandiae* (Fabricius)
Light-brown apple moth	*Epiphyas postvittana* (Walker)
A tussock moth	*Porthesia paradoxa* (Butler)
Leaf case moth	*Hyalarcta huebneri* (Westwood)
Cutworms	*Agrotis* spp.

DIPTERA

Queensland fruit fly	*Dacus tryoni* (Froggatt)
Ferment flies	*Drosophila* spp.

COLEOPTERA

Flower chafer	*Dilochrosis atripennis* Macleay
A green scarab beetle	*Diphucephala* sp.
Small monolepta beetle	*Monolepta divisa* Blackburn
A metallic flea beetle	*Haltica gravida* Blackburn
African black beetle	*Heteronychus arator* (Fabricius)
Elephant weevil	*Orthorhinus cylindrirostris* (Fabricius)
Vine weevil	*Orthorhinus klugi* Boheman
Fig longicorn	*Dihammus vastator* (Newman)

THYSANOPTERA

Plague thrips	*Thrips imaginis* Bagnall
Greenhouse thrips	*Heliothrips haemorrhoidalis* (Bouché)

HEMIPTERA

Grape phylloxera	*Daktulosphaira vitifolii* (Fitch)
Grapevine scale	*Parthenolecanium persicae* (Fabricius)
Long-tailed mealybug	*Pseudococcus longispinus* (Targioni-Tozzetti)
Rutherglen bug	*Nysius vinitor* Bergroth
Green vegetable bug	*Nezara viridula* (Linnaeus)
Green stink bug	*Plautia affinis* Dallas
Metallic shield bug	*Scutiphora pedicellata* (Kirby)
Pale cotton stainer	*Dysdercus sidae* Montrouzier
Coon bug	*Oxycarenus arctatus* (Walker)
Black cicada	*Melampsalta* sp.

ORTHOPTERA

Giant grasshopper	*Valanga irregularis* (Walker)
Spur-throated locust	*Austracris guttulosa* (Walker)

ARACHNIDA

ACARINA

Grape leaf blister mite	*Colomerus vitis* (Pagenstecher)
Grape leaf rust mite	*Calepitrimerus vitis* (Nalepa)
Bunch mite	*Brevipalpus lewisi* McGregor
Broad mite	*Polyphagotarsonemus latus* (Banks)

MOLLUSCA

GASTROPODA

SIGMURETHRA

Common garden snail	*Helix aspersa* Müller

ARTHROPODA
INSECTA — LEPIDOPTERA

Grapevine moth *Phalaenoides glycinae*

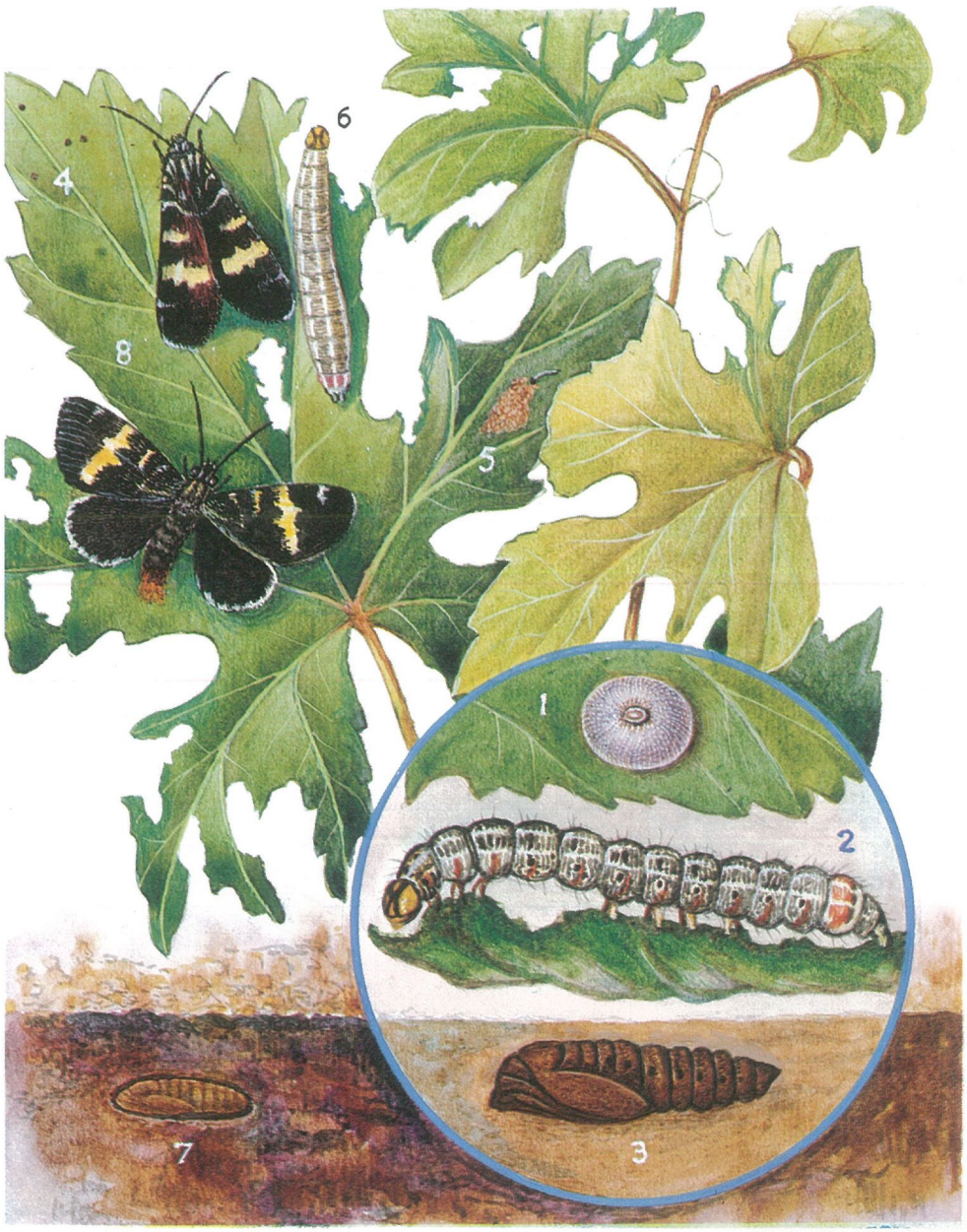
Importance and Distribution This insect, native to Australia, occurs wherever grapes are grown in New South Wales. It was described in 1822 when it was already common in all of the settled areas of Australia (Cordingley, 1980). It is a more serious pest of domestic vines than it is in commercial vineyards.

Conditions for Infestation Conditions which favour the lush growth of the vines also favour the attack of this pest.

Plants attacked As well as grapevines, fuchsias are commonly infested and may be defoliated. Virginia creeper and gloryvine are also attacked. Native species on which this pest has been recorded include *Gnaphalium luteoalbum, Glycine bimaculata, G. clandestina* and *Hibbertia* sp.

Description and Life History This handsome black moth has yellow markings, and a wingspan of about 6 centimetres. There are tufts of orange hair on the tip of the abdomen.

The eggs are flattened, finely ridged and steel grey. The caterpillar reaches 5 centimetres in length and is a blend of green,

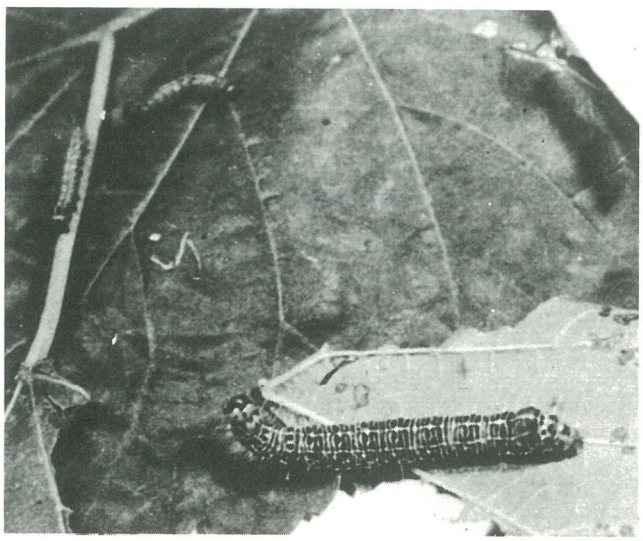


Grapevine moth
Phalaenoides glycinae

1 Egg; enlarged twenty times. **2** Fully-fed larva or caterpillar; enlarged twice. **3** Pupa; enlarged twice. **4** Eggs on leaf; **5** leaf damage by young larva; **6** larva, and leaf damage by old larvae; **7** pupa in soil; **8** adult moths; all actual size.

yellow and black, with red markings at the sides and a red band over the body at the hind end. Scattered white hairs give the body a grey appearance.

Vine moths overwinter as pupae, usually in the soil although some may be between leaves and debris cemented by the larva, or even in cracks in trellis posts. Moths emerge in early spring and lay eggs on stems and leaves. Larvae appear on vines in about mid-October, and a new generation of moths appears in December. There are usually two broods in the year, but there may be three with some overlapping.



Grapevine moth caterpillars. (Length, when fully developed, 5 cm)

Injury The caterpillars can strip a vine of its foliage in a short time; on young vines they may eat the plants back to the main stems. Large pellets of dark green excrement can be found beneath the vines.

Dispersal The moths are strong fliers and move during the day. Their flying ability has enabled them to reach all grape areas.

Control measures

NATURAL The grapevine moth is attacked at all stages by parasites and predators. Adults and larvae are easy prey for birds, particularly the bronze and pallid cuckoos. Predacious bugs such as *Oechalia schellenbergii* (Guérin-Méneville), the predatory shield bug, which is sometimes seen running about on the vines with a caterpillar on its beak, are important. Some parsitic wasps are also important, for example *Euplectrus* sp. Its eggs and larvae are often seen attached to a caterpillar which is still moving.

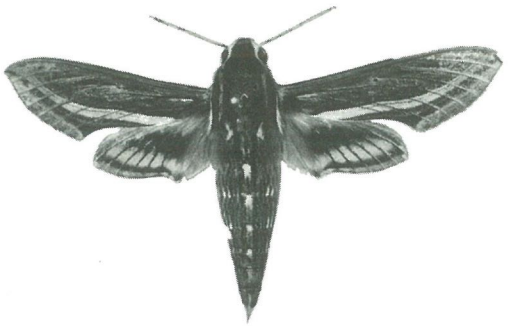
APPLIED Spraying with carbaryl 0.1 per cent is recommended.

Grapevine hawk moth *Hippotion celerio*

The larvae of this introduced moth are occasional pests of grapevines, but are more often seen on domestic vines than in commercial vineyards. The adults are handsome insects with small silvery markings on their light brown torpedo-shaped bodies, and they fly at night with a whirring sound. They are 6 to 7.5 centimetres across the outspread wings; the forewings are brown with a silvery stripe or band extending from the tips towards the bases of the wings, and the hindwings are mostly brown, with a black central patch, and bright pink near the body. The full-fed caterpillars are about 6 centimetres long and green or brown. The large oval eye-spot on the fourth body segment, and a smaller yellow spot on the fifth segment, distinguish it from other hawk moths. On the upper surface of the abdomen, near the hind end, there is a straight black spine. The larva pupates amongst leaves on the ground or just under the soil surface. The pupa is about 5 centimetres long and its hind end is prolonged into a sharp spine.

The larvae feed voraciously and can do much damage in a few nights. They are difficult to see because of their protective coloration, but they produce large barrel-shaped pellets of black excrement.

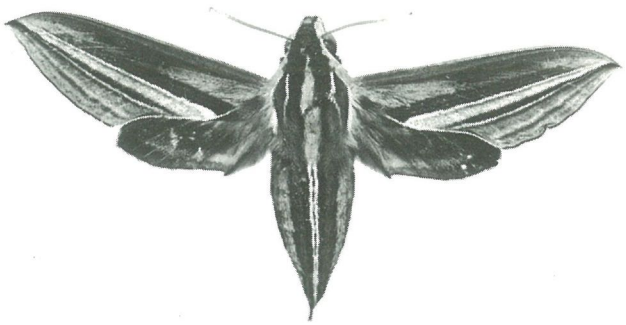
If control is necessary, the methods recommended above for the grapevine moth will be appropriate.



Grapevine hawk moth. (Wingspan 6 to 7.5 cm)

Vine hawk moth *Theretra oldenlandiae*

The adults are similar to *Hippotion celerio* but have no pink areas on the hindwings. The larvae feed on grapevines and related plants, as well as on sweet potatoes and their relatives.



Vine hawk moth. (Wingspan 6 to 7.5 cm)

Light-brown apple moth *Epiphyas postvittana*

The caterpillars of this moth feed on a great variety of hosts, including stone and pome fruits, and citrus. They can be found on many weeds which commonly grow in vineyards and on cover crops grown for green manure.

The grubs are pale green or yellow, and grow to a length of about 18 millimetres. They always feed under cover amongst leaves that they have folded and webbed together, or in webbed bunch clusters. When disturbed they wriggle violently and move further into shelter, or fall to the ground, or hang suspended by a fine thread from the leaf. The adults are small buff moths about 18 millimetres across the outspread wings, and are bell-shaped when at rest.

Light-brown apple moth larvae cause considerable harm to grapevines, especially in the irrigation areas, by webbing together and feeding on the leaves and young bunches. The pedicels and developing berries of very young bunches are chewed, causing the bunches to be thin and straggly. Webbing and sawdust-like excrement are found in the bunch. On ripening bunches, similar damage predisposes the bunch to mould development. The larvae appear in early spring and are very active again in autumn. In cool years they may be active in the summer also.

Control measures Many natural enemies – parasitic wasps, predatory insects and spiders – reduce numbers, but applied control is often necessary. It is believed that harm done to the natural enemies by the use of long-lasting insecticides is the main cause of the problem.

If grubs appear in significant numbers, it may be necessary to spray the grapevines at bud burst and repeat the treatment at intervals of three weeks until December. Autumn spraying may be needed in some years. Carbaryl 0.1 per cent gives good control.

More details of this pest will be found on page 96 under Apple Pests.

A tussock moth *Porthesia paradoxa*

The hairy brown and red caterpillars of this snow-white moth sometimes cause trouble in vineyards near the coast by feeding on the stalks of ripening grapes and on the skin near the stalks. They may cause heavy fruit-fall from individual vines. Their attack allows the entry of mould fungi and attracts ferment flies. The bunch is often spoilt.

The caterpillar reaches a length of about 2.5 centimetres and has a pair of red prominences on the back towards the hind end. Usually only a few vines here and there in the vineyard are affected but they may lose most of their fruit. Spraying the vines with carbaryl 0.1 per cent will control the caterpillars.

Leaf case moth *Hyalarcta huebneri*

Large numbers of case moth larvae sometimes feed on individual vines, eating many small holes in the leaves. Each caterpillar lives in and carries about its own case which it covers with chewed-off pieces of the leaves. The larvae are found hanging from the lower surfaces of leaves.

Control measures This insect has a wide host range and may be controlled by spraying with carbaryl 0.1 per cent.

More details of this moth will be found on page 26 under Citrus Pests.

Cutworms *Agrotis* spp.

Larvae of these moths often cause trouble amongst young vines in newly-planted vineyards. They feed at night, eating buds, shoots and sometimes the green bark. The cylindrical turgid-looking pink-brown or dark green grubs are found in the soil, not far under the surface, close to the vines. When exposed they coil into tight circles. They shelter in the soil by day.

Damage usually occurs in patches. Vines planted on ground which was weed-infested before being worked up are most likely to be infested, especially if the area has been flooded recently. Usually the moths will have laid their eggs on weeds. When the weeds are removed by cultivation the grubs feed on the young vines.

Control measures If the presence of cutworms is suspected, the area should be baited with lindane-bran before the vines are planted. If the damage is seen after planting, it has been found that it can be stopped quickly by spraying the soil at the base of each vine with endosulfan 0.07 per cent.

More details of these pests will be found on page 221 under Bean Pests.

DIPTERA

Queensland fruit fly *Dacus tryoni*

In some seasons, especially when the weather is humid, fly populations build up in numbers in summer on earlier fruits before 'stinging' grapes when they become available. This damage is rarely of importance in commercial vineyards, but it may be seen in household vines in coastal and northern inland areas.

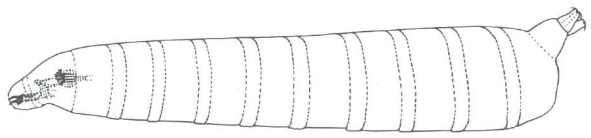
The maggots may not survive in the grapes, but the act of egg-laying initiates breakdown and decay.

Control measures Enclose ripening bunches in suitable bags, or spray-bait with maldison-protein hydrolysate when attack begins, as described for fruit fly control on page 34 under Citrus Pests.

Ferment flies *Drosophila* spp.

These small ferment or vinegar flies, about 3 millimetres long, are sometimes important, especially in coastal vineyards producing table grapes. If the weather in late summer causes some splitting of the berries, the flies will deposit eggs in the cracks from which small white maggots develop, causing fermentation and breakdown. The flies are brown or grey with reddish eyes, and are invariably attracted in great numbers to fermenting fruit or liquid. The larvae reach a length of about 4 millimetres and each has a bilobed protuberance on the last body segment. The robust pupae are shorter, and each one has a pair of horn-like respiratory tubes.

Control measures Ferment fly control is difficult when the conditions suit them. They breed extremely quickly. It is important to remove any possible site for breeding, such as decaying tomatoes or other fruit nearby and to spray these frequently with maldison or diazinon. Temporary relief from adults may be achieved with a non-residual insecticide, such as pyrethrum.



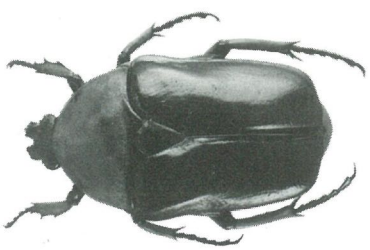
A ferment fly maggot. (Length, when fully developed, about 4 mm)

COLEOPTERA

Flower chafer *Dilochrosis atripennis*

These large clumsy but strong-flying scarab beetles often damage ripening grapes and other ripe fruits, such as figs or oranges, in autumn in the north-western districts of New South Wales. They descend on the vines by day and fly away at night. They eat out the pulp of the fruit almost completely, leaving only the skin. Bees are attracted to the damaged berries. The beetles are up to 4 centimetres long and 2 centimetres wide. The colour of the thorax is orange, the wing covers are reddish brown and the ventral surface of the beetle is black.

In home gardens, covering the bunches with bags is the most successful remedy when the attack has started or is known to be likely.



Flower chafer. (Length up to 4 cm)

A green scarab beetle *Diphucephala* sp.

These bright green shining beetles are about 8 millimetres long. They sometimes swarm on to vines in coastal districts in early summer, and can strip the foliage completely by nibbling it. They never attack a whole vineyard, but congregate on individual vines.

Control measures The beetles on a few vines can be destroyed by shaking them into a pan of sump oil, providing the attempt is made in early morning when they are comparatively inactive. If more vines are involved than can be handled in this way, spraying with carbaryl 0.1 per cent should be effective.

Small monolepta beetle *Monolepta divisa*

These beetles may swarm on to vines in the north-western inland areas in summer, nibbling young foliage and green bunches. They are 3 to 4 millimetres long, with a reddish yellow thorax and dark markings at the end of the wing covers. They congregate on individual vines which may be stripped of young fruit while other vines are left untouched.

Control measures These beetles can often be dealt with in home gardens by shaking them into a pan of sump oil. Otherwise, they may be sprayed with carbaryl 0.1 per cent.

A metallic flea beetle *Haltica gravida*

These beetles are about 6 millimetres long, purple-black, and characteristically jump when disturbed. They sometimes cluster on vines in inland areas in late spring and eat the foliage, stripping the leaves and gnawing the canes. Clusters of the beetles shelter in forks of vines or at the bases of stems during the day. They have been especially troublesome along the Murray River after flooding. The beetles breed on weeds, especially in low-lying situations, and it seems that they are driven out of their normal habitat by the rising water to become concentrated on nearby vines.

Metallic flea beetles can be dealt with in the same way as green scarabs, above.

African black beetle *Heteronychus arator*

Newly-planted vine cuttings in coastal vineyards are at times severely injured by African black beetles in spring or autumn. Attack is most likely when the vine planting follows paspalum pasture. The beetles that overwintered on the paspalum attack the vines just below ground level. They tear and tease the bark, and de-bark the young plants, some of which will be seen to wilt

and die. Similar damage may occur in autumn when beetles crawl into the vineyard from pasture land, or descend on it in a swarming flight for which this species is well known. A third method of infestation may occur on river flats when beetles are washed down the stream by floods and left behind by the receding water.

Control measures Control has been achieved when injury was first seen by jetting the base of each plant with DDT 0.1 per cent.

The African black beetle's habits are described more fully on page 295 under Tomato Pests.

Elephant weevil *Orthorhinus cylindrirostris*

This weevil, which is a native species, often causes considerable trouble in both coastal and inland vineyards. The adults feed on the bark of the canes and chew the buds, but it is the larvae which bore in trunks and roots of old vines, especially those lacking vigour, which may cause serious damage. Many different trees, including fruit trees, may be attacked.

The beetles emerge from about August onwards. They lay eggs in late spring or summer, and the larvae bore down through the trunk of the vine into the main roots. Later they bore upwards again and pupate. The adults bore out horizontally leaving a round hole in the trunk or a main arm. The channels are packed tightly with a fine sawdust-like material.

The adults chew patches of bark from the canes. These cause no great harm, but they are a sign that the weevils are active and that control measures should be applied.

Elephant weevil emergence holes in grapevine trunk.

Control measures Azinphos-methyl 0.05 per cent and carbaryl 0.1 per cent are effective used against adults several times as routine sprays in the spring.

More details are given on this insect on page 37 under Citrus Pests.

Vine weevil *Orthorhinus klugi*

This weevil has been known as a pest of vines since the early days (Froggatt, 1898). It is native and similar to elephant weevil, but smaller – about 7 millimetres long. It is reddish brown and hard-shelled. It drills holes in the canes with its long snout and inserts its eggs. The resultant larva, a legless grub, bores down through the stem before pupating at the end of its burrow. The adult bores its way out in early spring, leaving a round hole. The channel is packed with a fine flour-like dust.

Control measures suggested are similar to those for elephant weevil, above.

Vine weevil damage.

Fig longicorn *Dihammus vastator*

Grapevines are sometimes damaged by the larvae of this insect boring in stems. This was first reported as *Monohammus* sp. by Froggatt (1919). The beetles laid eggs on the bark of the main stem 10 to 12 centimetres above the ground, and the larvae entered the stem and bored upwards for a distance of about 30 centimetres.

Fig longicorn, which attacks passion vines, citrus and fig trees, is described more fully on page 195 under Fig Pests.

THYSANOPTERA

Plague thrips *Thrips imaginis*

Thrips have been suspected of causing reduced setting of the grape berries. Pimple-like swellings are seen on bunch stalks and pedicels of very young bunches. The tiny light brown insects are often seen in swarms among the bunches in spring, running about amongst the flowers and flying out in clouds when disturbed. Some light brown corky markings may be seen on the berries of some varieties.

The *Annual Report* of the Western Australian Department of Agriculture for 1961 (Anon, 1961) includes the following:

> For many years vignerons have believed that high thrips populations in bunches during the flowering stage may be detrimental to the setting of the fruit. Further insecticide trials during the year failed to reveal any difference in setting between sprayed and unsprayed bunches although counts showed that an excellent control of thrips had been achieved.

This agrees with experience in New South Wales during the thrips plague of 1931 in the Murrumbidgee Irrigation Area. Although grape bunches swarmed with both adults and nymphs, and egg-laying in the berry and bunch stems was so abundant that they were covered with small pimples, no evidence of any effect on setting was observed. Some slight injury in the form of small corky brown scabs on the berries was seen but this was of minor importance. In Western Australia limited damage of this kind was described by Sproul (1966). It would appear, therefore, that plague thrips is of little significance in grapes.

Greenhouse thrips *Heliothrips haemorrhoidalis*

Damage from this thrips is not uncommon on thickly-foliaged household vines, especially when they are grown on an overhead trellis. Such damage is insignificant in commercial vineyards. The injury shows up as a grey discoloration, speckled with black spots of excrement, with browning and withering of the leaves, and a mottled grey-brown scurfing on the berries. It does not warrant chemical control of the thrips.

Further details will be found on page 43 under Citrus Pests.

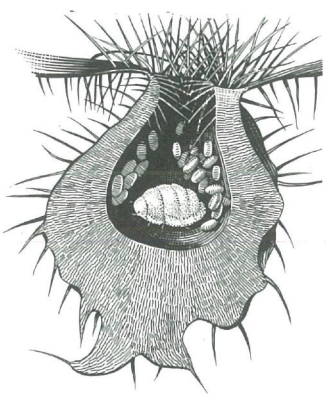
Greenhouse thrips damage on grape leaf.

HEMIPTERA

Grape phylloxera *Daktulosphaira vitifolii*

This aphid, previously *Phylloxera vastatrix*, has been one of the most feared of all insects that attack plants. A native of North America, it was introduced to France in 1863. Before it was controlled by the use of resistant stocks, it had destroyed more than 1 000 000 hectares of vineyards there, as well as spreading to other countries. The root-infesting form is responsible for the damage (another form of the insect makes leaf galls that do little harm to the vine). Galls are formed on the roots and this is usually followed, on European vines, by tissue breakdown and rotting. The severity of the damage is greatly influenced by soil type. The first sign of infestation in a vineyard of susceptible vines is stunting of a few vines, with early yellowing of foliage. Later, adjacent vines become affected and the infested area becomes obvious. This concentric development, with the central vines dead or dying, and the gradual extension of the damage is typical.

Grape phylloxera leaf galls. P.R.I., Dept of Ag. Vic.



Cross-section of grape phylloxera leaf gall.

Vines native to the central and eastern United States, *Vitis riparia* and *V. rupestris*, are resistant to phylloxera (Quayle, 1938), while the European grapevines, *V. vinifera*, are usually seriously harmed by the root galls. The problem can generally be solved by replanting infested vineyards with European vines grafted on to resistant (American) roots.

In New South Wales, phylloxera was first recognized at Camden in 1884. It was restricted by vigorous Government quarantine measures to an area about 24 kilometres by 8 kilometres in the County of Cumberland in which there were scattered small vineyards – a fortunate circumstance – and to some infestations at Albury and Corowa. Phylloxera was widespread and most destructive in Victoria, which, as a result, lost its position as the leading vine-growing State in Australia. Quarantine measures were successful in protecting South Australia which became the leading wine-producing State. Provision of resistant grape stocks was organized by the Government in New South Wales with the establishment of propagation stations. The insect has been kept away from the Hunter Valley and the inland irrigation areas where most vines are planted without resistant stock.

Phylloxera may be dispersed as the winged insect or by wingless forms crawling from row to row, but the most important method of dispersal is by the movement of galls or pieces of infested root or plant material. These may be moved on or by cultivating implements, picking boxes, weeds, cuttings and rooted vines, and by man and animals. The movement of plant parts undoubtedly constitutes the chief danger; this includes cuttings that have been 'heeled in' or rooted in ground which was previously 'phylloxerated'.

The phylloxera problem in New South Wales around the turn of the century has been described by Despeissis (1892), Preedy (1896) and Blunno (1901, 1904).

Control measures These are based on quarantine regulations which prevent the movement of any vine material, other than fruit, from the infested area, and on the planting of resistant stocks. The use of resistant stocks is compulsory in New South Wales in areas where the pest has occurred, and encouraged in other areas. These measures have proved to be extremely satisfactory in Australia as indeed they have in other countries.

Grapevine scale *Parthenolecanium persicae*

Importance and Distribution This scale is common in both coastal and inland areas. While it is often confined to household vines, it has also produced some heavy infestations in inland irrigated vineyards.

Conditions for Infestation Mild moist seasons suit the grapevine scale best and certainly stimulate the development of sooty mould which is the main damage resulting from an attack by this pest.

Plants attacked Several stone fruit trees, especially plums, are infested as well as vines.

Description and Life History The grapevine scale is elongate-oval, dark brown and rather shiny. It reaches a length of 6 millimetres. The young scales are yellow and about 2.5 millimetres long when they appear on the leaves in autumn.

The scales overwinter as adults on old wood and mature canes. Eggs form under the scale covers in early spring. The larvae hatch in about late November. The six-legged crawlers go to the leaves and settle down, mostly on the undersurfaces along the chief veins. They produce copious clear sticky honeydew which falls on to leaves, canes and bunches. When the leaves are nearly ready to fall in late autumn the scales migrate to the wood where they develop into the large dark adults.

Injury Injury to the leaves by the feeding of even very large numbers of scales is slight. No wilting is seen. The only harm results from the sooty mould which can down-grade the appearance of the fruit for market.

Dispersal As with most scales, transport of the young stages by wind is probably the main means of dispersal. Scales are usually introduced to a vineyard on cuttings or buds.

Control measures

NATURAL Grapevine scale is normally controlled by its many natural enemies, including several wasp parasites and two predators – mealybug ladybird, *Cryptolaemus montrouzieri*, and scale-eating caterpillar, *Catoblemma dubia*.

APPLIED Spraying of the vines in winter, after pruning, with superior dormant oil 3 per cent is effective. If control in the summer should be considered necessary, spray with either maldison 0.1 per cent plus petroleum oil 1 per cent or ethion 0.075 per cent-in-oil 1.25 per cent. The lower surfaces of leaves must be covered.

Long-tailed mealybug *Pseudococcus longispinus*

Importance and Distribution Mealybugs often attack grapevines in both coastal and inland districts. They can be extremely troublesome in grapes grown for the table. They spoil many bunches, and make it necessary to inspect and trim bunches as they are packed. In wine grapes and sultanas, mealybugs prevent the correct sugar development. In sultanas, the sooty mould growth interferes with dipping and the attainment of an even-coloured product. Infested bunches are unpleasant for the pickers to handle.

Conditions for Infestation Any conditions promoting vigorous vine growth will favour mealybug development. Vines with heavy foliage – sultanas, currants, and some other varieties – are often heavily infested, while adjacent vines with sparse foliage, such as Gordo Blanco, are not affected. Vines on deep fertile well-watered soil will have mealybugs, whereas less vigorous vines on heavier soils nearby will not suffer.

Plants attacked Mealybugs are common insects on a wide variety of plants, especially those with heavy foliage. Citrus and many ornamental shrubs, and even weeds, may be infested.

Description and Life History The adult female is soft, elongate-oval in outline, flattened, pale yellow, up to 6 millimetres long and covered with mealy white wax. There is a fringe of white filaments around the body and, at the posterior end, these are at least as long as the body. Eggs are laid singly beneath the body and hatch almost immediately. Adult males are minute delicate two-winged insects, with well-developed legs and antennae, which may be seen in numbers hovering over infested plants. They do not feed as the mouthparts are aborted.

Mealybugs overwinter as adults under the rough bark of older canes, in the crown of the vine and sometimes in the cracks on trellis posts. In spring they move on to new growth. In early summer they are along veins on the backs of leaves in the centres of the vines. They do not usually enter bunches until January.

For further information on mealybugs see page 66 under Citrus Pests.

Injury The actual feeding is of only slight significance. The mealybugs feed on the fruit stalks and berries, and secrete honeydew, some of which can be seen as spherical drops covered with mealy white powder. Ants are attracted to the honeydew, and sooty mould develops on it.

Dispersal Mealybugs can crawl from one vine to another, and ants are known to transport them.

Grape bunch infested by mealybugs.

Control measures

NATURAL In vines, probably the most important enemies are the larvae of green lacewings, *Chrysopa* spp. Wasp parasites and the mealybug ladybird, *Cryptolaemus montrouzieri*, are also effective. These natural enemies are most important in keeping infestations at low levels. Injudicious spraying with residual insecticides, such as DDT, or with a strong Bordeaux mixture has been followed by a rapid increase in mealybug infestation.

The ants which swarm over infested plants tend to deter useful parasites.

In South Africa, where the Argentine ant is a common inhabitant of vineyards, very good control of the mealybug, *Planococcus citri*, was achieved following the control of ants by the application of dieldrin to the lower parts of the vine trunks, trellis supports and anchor wires (Durr, 1955).

APPLIED For summer treatment, susceptible vines should be inspected in late spring to find whether mealybugs are present on the backs of leaves in the centres of vines. If they are to be treated, parathion 0.05 per cent, or maldison 0.1 per cent, or diazinon 0.05 per cent spray should be directed at the undersides of leaves and the crowns and bunches. It may be necessary to treat only occasional vines. Because of the high toxicity rating of parathion, great care should be exercised in handling and using it.

Where mealybugs have been a serious pest in the previous season, a winter spray of ethion 0.075 per cent-in-oil 1.25 per cent is advisable.

Rutherglen bug *Nysius vinitor*

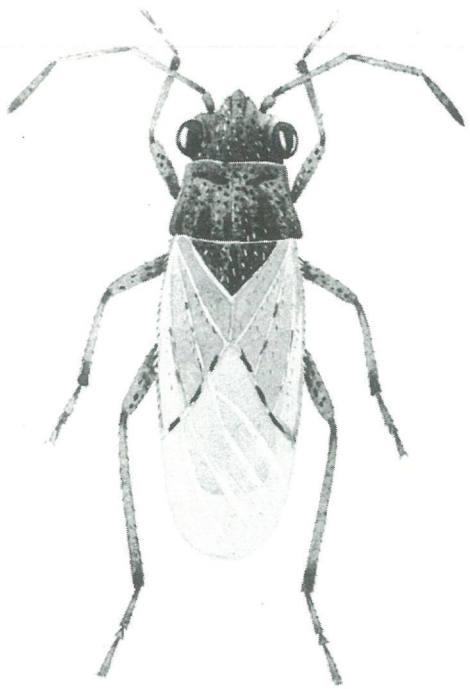
Importance and Distribution This small native bug is widely distributed in New South Wales and other States. It can be a severe pest of young grapes and many other crops. In some years it reaches plague numbers in spring and summer.

Conditions for Infestation In lush seasons, Rutherglen bugs breed up to large numbers on weeds in winter and spring. When hot dry weather arrives in late spring and the weeds dry, huge populations of the bugs, winged or part-grown, swarm on to nearby green plants. The effect is often accentuated by the cultivation of soil between the rows of vines at that time.

Plants attacked Many fruits and vegetables – particularly grape, stone fruits, young citrus and potato – and other crops and ornamentals may be attacked. The bugs develop on many weeds, such as capeweed, cudweed, sand spurry, thistles and other composite plants, and the young bugs feed avidly on the seeds of plants (Kehat and Wyndham, 1972).

Description and Life History The adult female is about 5 millimetres long, narrow-bodied and grey-brown with black eyes. The two pairs of wings are silvery. The male is slightly smaller and darker. The eggs are about 1 millimetre long and cream, but become amber with age; they are deposited on the flower heads of weeds, or on ground trash, in groups of about six. The nymphs are amber when hatched but they soon grow darker. There are five moults to the adult stage. The nymphs are shorter and stouter than the adults. Wing buds appear in the fourth instar.

The bugs overwinter as adults amongst weeds and trash near the ground surface. In early spring they lay eggs; one female may deposit 400. Incubation takes about a week. The development time from egg to adult is about a month. All stages have an unpleasant odour.



Rutherglen bug. (Length about 5 mm)

Injury As host weeds dry off, the bugs migrate across the soil. Mass movement may be triggered off by circumstances such as the disturbance of a passing vehicle, especially just before a storm. The migration is apparently aimless, but any succulent plants encountered are likely to be swarmed over and sucked almost dry. Leaves wilt, green bark shrivels, and young vine rootlings can be killed by the attack. The surfaces on which the bugs feed become grey with their excrement.

Later in the year swarms of adult bugs may arrive and congregate on the vine foliage and on bunches, causing some wilting and shrivelling, and some fouling of the fruit. If the bugs are in the vines at picking, they are an irritation to the workers as they can cause perceptible pricks with their horny sucking beaks.

Dispersal The immature bugs have been known to travel as far as about 100 metres in mass migrations. The adults are strong fliers. Sometimes they swarm to lights in large numbers.

Control measures

NATURAL Rutherglen bug populations are regulated mainly by the weather. They are most numerous in dry spring weather after a wet winter. Heavy rain in spring may kill huge numbers, while warm humid conditions produce outbreaks of fungal diseases that may also help to destroy them.

APPLIED Early ploughing of a breeding area of weeds is very effective. Deep ploughing in late August can eliminate a large population. Both nymphs and adults are quite easily killed by mechanical action in late winter, whereas the population becomes much more hardy later in the year. The bugs do not breed in cover crops, so significant control can be achieved by growing a leguminous or cereal cover crop amongst the vines and turning it in before the end of August.

A method that has been used in an emergency to prevent migrating wingless bugs crawling from breeding areas into crop land is to plough a deep furrow along the boundary. Bugs fall in and the majority fail to get out. If holes are dug in the bottom of the furrow, at intervals of about 5 metres, bugs collect in the holes and can be killed with maldison spray.

When the bugs are attacking young vines, spraying with maldison 0.06 per cent will kill all stages contacted by the insecticide. Mevinphos 0.05 per cent spray has also been found to be very effective. Great care should be exercised when handling mevinphos as it is very toxic to the user. The soil around each vine should be sprayed, as well as the vine itself.

Plant bugs of occasional importance on grapes

Several plant bugs attack ripening grapes and may be very troublesome, especially to household grapevines. They are rarely important in commercial vineyards. The bugs suck the juice out of the berries which then wilt and shrivel. Attack usually results from the bugs breeding up in numbers on nearby weeds and migrating to the vines in dry weather.

GREEN VEGETABLE BUG, *Nezara viridula*, used to be an important pest, but it has not been nearly as destructive since the introduction of certain parasites to Australia.

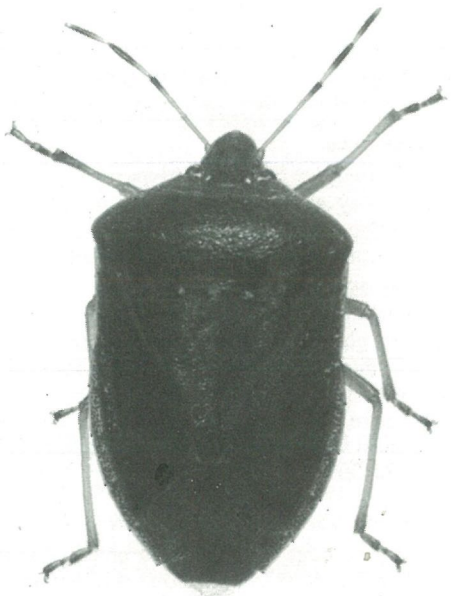
GREEN STINK BUG, *Plautia affinis*, is smaller than the green vegetable bug but similar in shape. It has a notably offensive smell.

METALLIC SHIELD BUG, *Scutiphora pedicellata*, adult is 14 millimetres long, shield-shaped, and a metallic green or blue and black in colour, with some red markings. It has been found on native figs and tea-trees, and on many cultivated trees and garden plants.

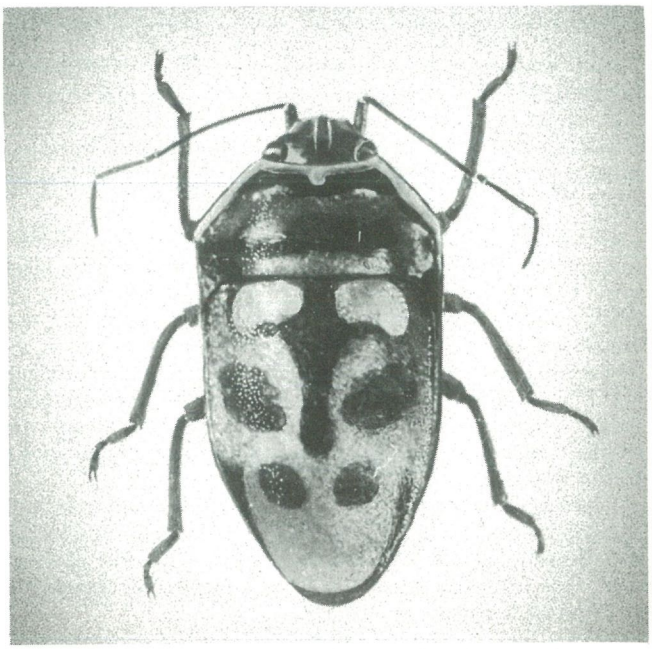
PALE COTTON STAINER, *Dysdercus sidae*, is about 12 millimetres long, and rather narrow and rectangular. It is brownish grey with a conspicuous dark spot in the centre of each forewing. It feeds mainly on various native plants, but sometimes damages stone fruits.

COON BUG, *Oxycarenus arctatus*, is 3 millimetres long. Each forewing has a dark area in the middle. The young are red, and may often be seen clustering on weeds or on fence posts and stumps.

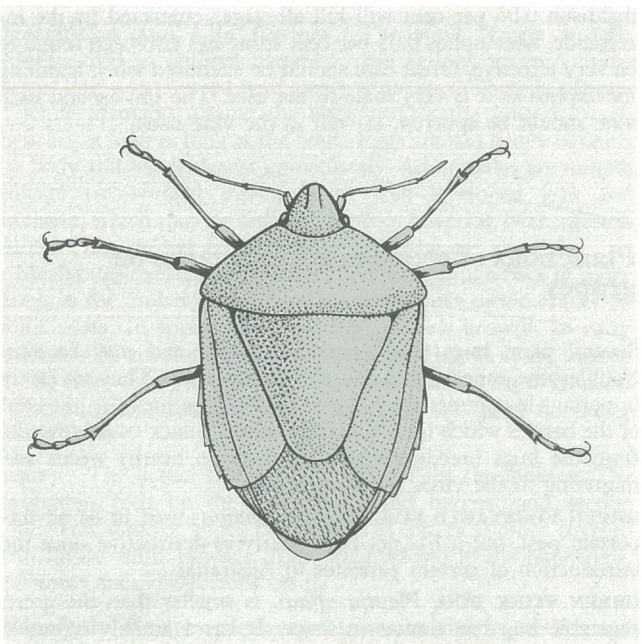
Control measures If and when the attack seems to be becoming serious, all these plant bugs may be dealt with by spraying with maldison 0.075 per cent.



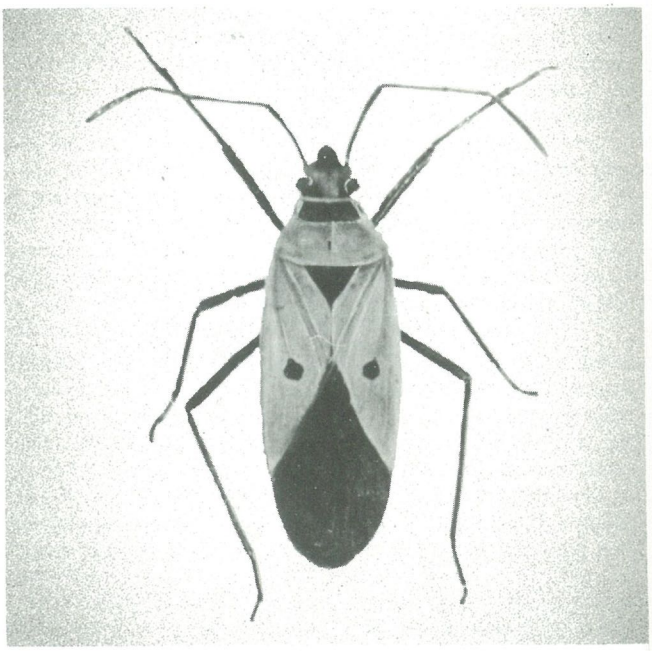
Green vegetable bug, *Nezara viridula*. (Length about 15 mm)



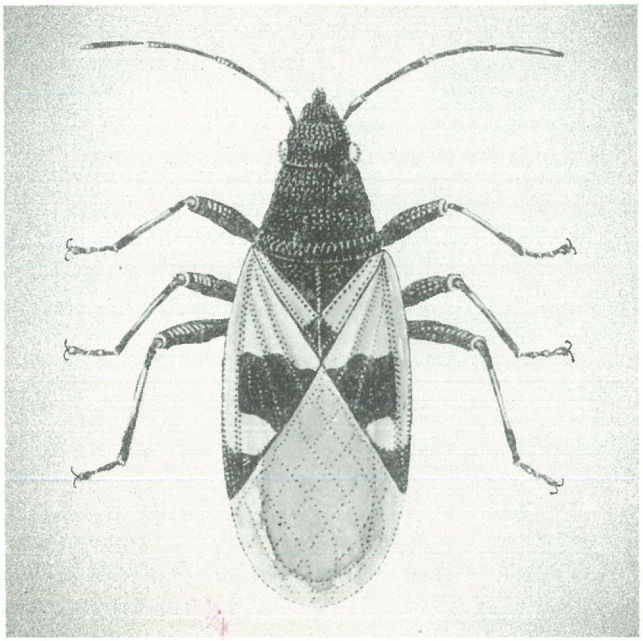
Metallic shield bug, *Scutiphora pedicellata*. (Length 14 mm)



Green stink bug, *Plautia affinis*. (Length about 8 mm)



Pale cotton stainer, *Dysdercus sidae*. (Length about 12 mm)



Coon bug, *Oxycarenus arctatus*. (Length about 3 mm)

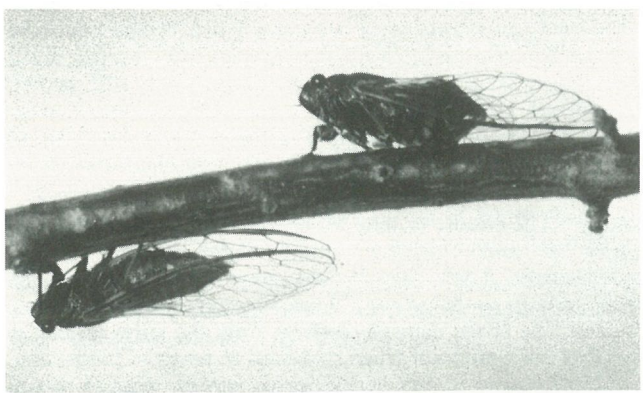
Black cicada *Melampsalta* sp.

Grapevines in the Hunter Valley have occasionally been invaded by black cicada adults which have caused injury by laying their eggs in the vines. They may be very numerous and fly out of the vines in swarms when the foliage is disturbed (Greenup, 1967).

The small black clear-winged females pierce the current season's canes with their ovipositors to insert their eggs. Up to 39 holes per 2.5-centimetre length of cane have been counted. The eggs are slightly more than a millimetre long and about five are deposited in each puncture. The eggs hatch in eight or ten weeks and the tiny nymphs drop to the ground.

The injury resulting from the puncture causes some shoot dieback, but has not been shown to reduce yields.

The damage is likely to be well advanced before it is noticed, the attack lasts for only a short time and, as the resultant injury is slight, control efforts do not seem to be warranted.



Black cicadas.

ORTHOPTERA

Locusts and grasshoppers of occasional importance

Several species of locust or grasshopper attack grapevines in inland areas, usually in the autumn. They feed on the foliage and on fruit if it is available. They have voracious appetites and can do a great deal of damage in a single night, leaving plant tissues ragged or torn. The injury is not reported from commercial vineyards, but is confined to household vines. The giant grasshopper, *Valanga irregularis*, is the most commonly implicated, and nymphs as well as adults may be present. The adult reaches a length of 10 centimetres. The spur-throated locust, *Austracris guttulosa*, may also be involved.

Control measures Spraying with maldison 0.1 per cent should be effective if control of these locusts is needed.

ARACHNIDA ACARINA

Grape leaf blister mite *Colomerus vitis*

Importance and Distribution The grape leaf blister mite causes blisters on the leaves and it has a morphologically identical form which infests growth buds. This is an introduced species which is now found wherever vines are grown in New South Wales. In some seasons, and on some varieties, the blister mite does economic damage, but the effect of the bud mite on yield is not clearly defined.

The distinctions between the blister mite and the bud mite forms have been described by Keifer (1944) and Smith and Stafford (1948). May and Webster (1958) at Merbein, in Victoria, studied the bud mites during several years and considered that, at least on the variety Waltham Cross, they caused some buds to fail to develop normally, with some resultant reduction in yield. Mites were present in the buds of all varieties. Injury by bud mite causes stunting of the canes, short internodes at the base, zig-zagged shoots and dead overwintering buds. In the Murrumbidgee Irrigation Area the Ohanez variety seems to be the most susceptible.

In California, the seasonal activity of the bud mite form and its damage have been described by Kido and Stafford (1955).

Conditions for Infestation Although the blister mite is seen in inland as well as in coastal vineyards, it is favoured by warm moist conditions. Inland, the mite shows up most obviously in seasons of above-average spring or summer rainfall.

Plants attacked This mite is confined to grapevines but both forms prefer some varieties to others. Blister mite does best on Gordo Blanco, Black Hamburg, Black Muscat, White Shiraz and Rutherglen Tokay. It occurs commonly on the Zante currant,

Grape leaf blister mite
Colomerus vitis

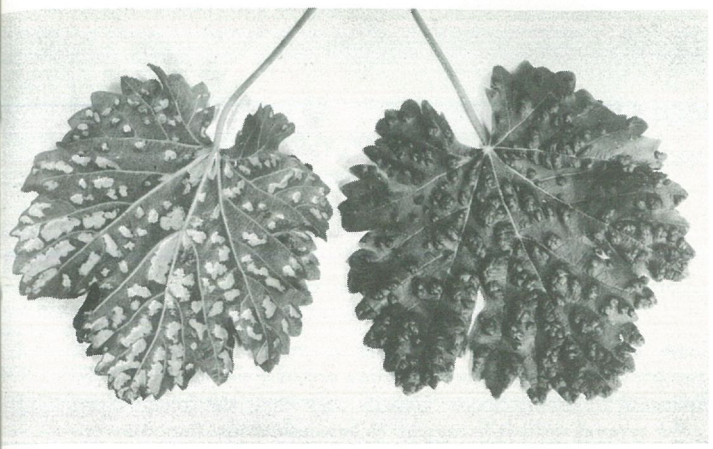
1 Mites on undersurface of leaf; enlarged seventy times. **2** Undersurfaces of leaves showing hairy development or erinose condition caused by mites, early development yellowish and old infestations reddish; **3** upper surface of leaf showing blister-like formations caused by the mites feeding below; all actual size.

but only very occasionally on sultanas. The bud mite strain is present on most varieties, but appears to do no harm except possibly on Ohanez and Waltham Cross.

Description and Life History The mites are 0.2 millimetre long, white or creamy and worm-like. They have two pairs of legs near the head end. Both males and females are produced. The blister mite and bud mite forms are distinguished only by their habitat on the vine.

The blister mite overwinters under bud scales, and moves out in the spring to feed on the young leaves. As the blister or 'erineum' is produced, the mites multiply in the protection provided by the felt-like leaf hairs. They do not move about the vine to any extent but produce many generations in the year. In autumn they leave the ageing leaves and seek the protection of the bud scales.

Injury The erinose or mite blister injury shows on the young leaves as small circular yellow areas, usually on the undersurfaces. Later they become brown and felt-like. The upper surfaces produce raised blister-like and often red or purple patches. The actual damage resulting from the mites feeding is probably not significant when measured in terms of production. If the infestation is very heavy, leaves may be reduced in size and distorted so that the bunches of grapes may be unduly exposed to the sun.



Grape leaf blister mite injury on upper and lower surfaces of leaves.

Dispersal Infestation of a vineyard could take place as a result of wind dispersal, or the transport of mites by insects or birds, but the introduction on plants in a new planting is probably the main method.

Control measures

NATURAL Predacious mites are recorded as being important natural enemies of eriophyid mites, as also are hover fly larvae, lacewings, and predacious thrips (Kido and Stafford, 1955).

APPLIED Winter spraying with lime-sulphur (polysulphides) 1 per cent just before the buds swell is the best control for blister mite. Thoroughness of spraying is essential. The treatment should be applied in any winter following a year in which the blisters have been obvious. Sulphur 0.4 per cent spray or 50 per cent dust is also effective when applied in the growing season.

No satisfactory control of the bud mite strain has been demonstrated, and in Australia it has not been proved to be a significant pest.

Grape leaf rust mite *Calepitrimerus vitis*

This eriophyid mite is common on grapes in coastal districts and in some seasons it can also be seen in the inland.

Damage takes the form of a general brownish purple colour on the leaves, especially on the upper surfaces along the main veins and midrib where mites are more numerous than on the lower surfaces. The coloration follows the rupturing of the epidermal cells by the mites. If leaf browning is very extensive, many leaves may fall and, if this happens before harvest, the bunches may suffer from sunburn. However, such extreme infestation is unusual.

The mites are tiny but move quite actively. They moult twice, and the white cast skins, like tiny pieces of white tissue, are sometimes all that can be seen when investigating the damage.

Control measures Routine applications of lime-sulphur, or sulphur spray, or dust for blister mite control usually hold rust mite damage in check.

Bunch mite *Brevipalpus lewisi*

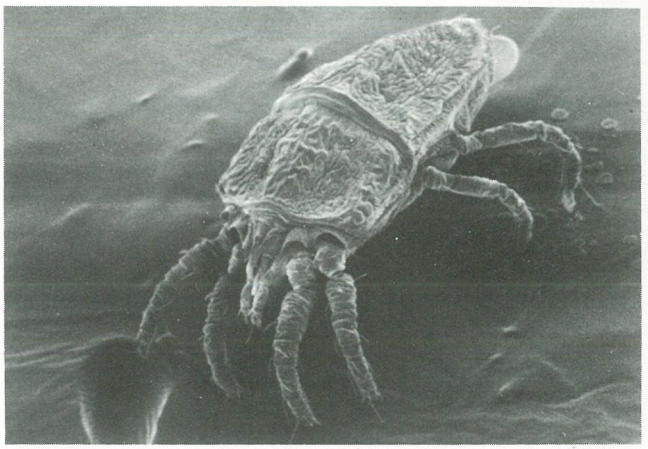
Importance and Distribution These tenuipalpid mites occur in all vine-growing districts in New South Wales, but it is in the inland that they do significant and sometimes severe damage. In most years their activity is not of major commercial importance.

Conditions for Infestation Hot dry weather in summer may lead to a build-up of the pest and quite serious injury.

Plants attacked These mites are best known as pests on grapevines.

Description and Life History The adults are very small, about 0.3 millimetre long, flat and rather shield-shaped, and reddish brown. The eggs are oval and bright red.

The adults spend the winter under outer bud scales and under rough bark at the bases of the canes. In spring they move out and feed on the bark of the developing canes, and later on the undersurfaces of leaves. Then they move to the bunch stalks, berry pedicels, and berries. The eggs are scattered amongst the mite colonies. The six-legged nymphs, which are lighter-coloured than the adults, subsequently moult to eight-legged nymphs and, after another moult, become adult.



Brevipalpus sp. mite. (Length 0.3 mm)

Injury The canes may be browned at the base, and often scarred and roughened. The stalks of bunches may also be scarred and browned so that the berries shrivel. Sometimes the skins of the berries are browned and roughened. Heavy infestation of leaves may cause premature leaf-fall. Probably the worst result is rapid withering of bunch stalks and pedicels at and after harvest. The bunch looks as if it has been cut for some time and the market presentation is adversely affected. This is particularly important with table varieties such as Black Muscat, Cornichon and Waltham Cross which are all commonly infested.

Early signs of bunch mite activity are seen in about November and are usually confined to the bases of canes. Injury consists then of tiny slightly-raised black spots. As activity increases, the spots merge into dark brown scar tissue. Then the mites spread along the canes, and eventually concentrate on the bunch stalks and the berry pedicels. They can cause excessive thinning of the berries, and these early symptoms may be confused with those of dead arm disease or with black spot. As mite activity increases, the symptoms become more pronounced and the stalks and pedicels become covered with dark brown raised scar tissue. The damage partially starves the berries, preventing high sugar

Bunch mite injury.

content and reducing size and weight. Berries can dry out while still on the vine during a hot summer. The mites can continue to feed during packing and transport, so bunches of table grapes at the market will be flabby, some berries will have fallen, and fruit that was formerly attractive shows up poorly.

Control measures

NATURAL It is thought that ladybirds, predacious mites and predacious thrips assist in regulating the population.

APPLIED Winter spraying just before the buds begin to swell with lime-sulphur (polysulphides) 1 per cent is the most satisfactory method of control.

During late spring and early summer, spraying with dispersible sulphur 0.4 per cent or dicofol 0.04 per cent, or dusting with sulphur 50 per cent is recommended. Thorough application to the vines is essential.

Broad mite *Polyphagotarsonemus latus*

These mites occasionally cause injury to household vines in summer when growing conditions are good and there is abundant tender young growth on the vines. The growing-tip leaves are narrowed and in-rolled at the edges, and have a bronze tinge. The injury is similar to that caused by 2,4-D weedicide. Control action is not likely to be needed.

MOLLUSCA
GASTROPODA SIGMURETHRA

Common garden snail *Helix aspersa*

Snails are common pests of vines in low-lying areas in wet seasons, and they have become important in lower Murray River vineyards following floods. Usually they chew the foliage close to the ground until it is ragged. When numerous, they may reduce leaves to a few veins.

Snails can be dealt with by spraying with Bordeaux mixture or by using poison baits as described on page 82 under Citrus Pests.

References

Anon (1961). *Annual Report Department of Agriculture, Western Australia.* Perth.

Blunno, M. (1901). Phylloxera-resistant stocks. *Agricultural Gazette of New South Wales* **12**: 1554–62.

Blunno, M. (1904). Reconstruction of phylloxera-infected vineyards on phylloxera-resistant stock. *Agricultural Gazette of New South Wales* **15**: 364–82.

Cordingley, C. L. (1980). Biology of the grapevine moth, *Phalaenoides glycine* Lewin (Lepidoptera: Agaristidae). *Journal of the Australian Entomological Society* **19**: 181–7.

Despeissis, A. (1892). Phylloxera of the vine. *Agricultural Gazette of New South Wales* **3**: 13–29.

Durr, H. J. R. (1955). The control of the Argentine ant (*Iridomyrmex humilis*) by means of DDT, chlordane and dieldrin. *Journal of the Entomological Society of Southern Africa* **18**: 7–12.

Froggatt, W. W. (1898). Fruit-tree and vine pests. *Agricultural Gazette of New South Wales* **9**: 41–7.

Froggatt, W. W. (1919). A vine-destroying longicorn beetle (*Monohammus* sp.). *Agricultural Gazette of New South Wales* **30**: 129–31.

Greenup, L. R. (1967). Cicadas as pests in New South Wales. *Agricultural Gazette of New South Wales* **78**: 42–6.

Kehat, M. and Wyndham, M. (1972). The effect of food and water on development, longevity and fecundity in the Rutherglen bug, *Nysius vinitor* (Hemiptera:Lygaeidae). *Australian Journal of Zoology* **20**: 119–30.

Keifer, H. H. (1944). Eriophyid Studies XIV. *California Department of Agriculture Bulletin* **33**: 21.

Kido, H. and Stafford, E. M. (1955). The biology of the grape bud mite *Eriophyes vitis* (Pgst). *Hilgardia* **24**: 119–42.

May, P. and Webster, W. J. (1958). The bud strain of *Eriophyes vitis* (Pgst) in Australia. *Journal of Australian Institute of Agricultural Science* **24**: 163–6.

Preedy, W. (1896). Phylloxera. *Agricultural Gazette of New South Wales* **7**: supplement following p420. 3pp.

Quayle, H. J. (1938). *Insects of Citrus and Other Subtropical Fruits.* Comstock Publishing Co., Ithaca, N.Y. 583pp.

Smith, L. M. and Stafford, E. M. (1948). The bud mite and the erineum mite of grapes. *Hilgardia* **18**: 317–34.

Sproul, A. N. (1966). Thrips damage of grapes. *Journal of Agriculture of Western Australia* **7** (Fourth Series): 177, 179.

TROPICAL FRUITS

Tropical fruit pests

Tropical fruits are grown in New South Wales mainly on the north coast from Port Macquarie. Bananas, avocados, macadamias, pineapples and passionfruit have been grown there for many years, during which time their insect pests have been carefully investigated. Other tropical fruits, such as custard apple, litchi, papaw, mango, sapote, Chinese gooseberry and tamarillo, have been cultivated commercially more recently and their insect pest problems are still being evaluated.

The insect pests of banana, avocado, macadamia, pineapple and passionfruit are discussed on the following pages.

Banana pests

Banana growing in New South Wales is an important industry on the coast north of Port Macquarie.

The ideal areas for planting bananas are warm, sheltered and frost free. The crop is grown mostly on steep hillsides with a northerly aspect and from about 60 to 250 metres above sea level. The main variety is now Williams, with some Cavendish still being grown in the warm coastal areas of the Tweed, Brunswick and Richmond districts.

A plantation is established by planting vegetative material – suckers, corms, or bits (cut pieces of corm). Most planting is done in October–November, and the first bunches will emerge in the following November to be harvested between April and September. When a bunch is cut, the pseudostem on which it was produced is removed. By that time the plant will have produced young suckers around the base; it is usual to remove most of them while allowing one or two to survive as selected 'followers'. In New South Wales production of bunches becomes greatest in the summer.

The bunch or inflorescence emerges from between the leaves at the top of the pseudostem and, after it appears, no more leaves are produced by that pseudostem. At first the inflorescence points upwards, but as the stalk lengthens it turns over and hangs down. Bunches take three to eight months to mature, depending on the season, and are covered with plastic to protect the fruit. They are harvested and transported to market as 'hard-green' fruit, and ripened under controlled temperatures in an atmosphere containing ethylene.

The major banana-growing areas in New South Wales are quarantine areas under the *Plant Diseases Act, 1924 (as amended)*. The *Act* requires any person intending to plant bananas in a quarantine area to obtain a permit from the Department of Agriculture, and no banana plant or part of a plant, except the fruit, may be moved within or into a quarantine area without a permit. Under these requirements, framed for the control of bunchy top virus disease and banana weevil borer, the ground must be kept free from weeds to a distance of not less than 2 metres around each banana plant.

Bananas are grown in relatively high rainfall areas (usually more than 125 centimetres per annum), but dry spells, especially in the spring months, can be harmful so many plantations have supplementary irrigation. Weed control is most important and this is generally accomplished with the use of herbicides. Cercospora leaf spot and speckle are the main fungus diseases, and treatment for them may be necessary. Infestations of several insect or mite pests, such as banana weevil borer, banana aphid, strawberry spider mite and banana rust thrips, may also require the use of sprays. Owing to the steepness of most plantations, sprays are mostly applied from low-volume misting machines (either shoulder-mounted or on four-wheel drive vehicles) and aircraft.

In years of heavy Queensland fruit fly infestation, the flies may attack ripening fruit in the plantations, but they only rarely affect 'hard-green' fruit. Fruit fly is not a significant cause of fruit loss, but restrictions are imposed on marketing to avoid the possibility of fruit fly being carried to other States or the Murrumbidgee Irrigation Area.

An account is given on pages 173 to 178 of the pests of banana listed below.

ARTHROPODA

INSECTA

LEPIDOPTERA	
Banana fruit caterpillar	*Tiracola plagiata* (Walker)
DIPTERA	
Queensland fruit fly	*Dacus tryoni* (Froggatt)
COLEOPTERA	
Banana weevil borer	*Cosmopolites sordidus* Germar
African black beetle	*Heteronychus arator* (Fabricius)
Monolepta beetle	*Monolepta australis* (Jacoby)
THYSANOPTERA	
Banana rust thrips	*Chaetanaphothrips signipennis* (Bagnall)
Banana silvering thrips	*Hercinothrips bicinctus* (Bagnall)

HEMIPTERA

Banana aphid	*Pentalonia nigronervosa* Coquerel
Latania scale	*Hemiberlesia lataniae* (Signoret)
Cyanophyllum scale	*Hemiberlesia cyanophylli* (Signoret)

ARACHNIDA ACARINA

Strawberry spider mite	*Tetranychus lambi* Pritchard & Baker

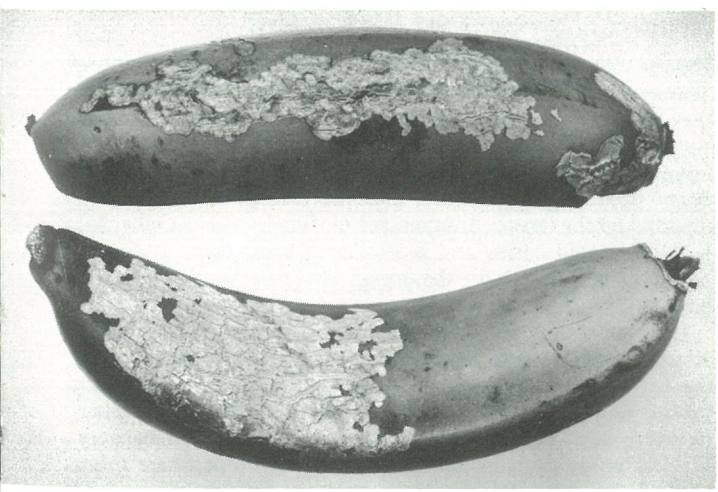
INSECTA LEPIDOPTERA

Banana fruit caterpillar *Tiracola plagiata*

This caterpillar sometimes occurs in plague numbers and can damage up to 20 per cent of the crop in some plantations. Cluster caterpillar, *Spodoptera litura*, may also damage the fruit occasionally.

Banana fruit caterpillars generally migrate to plantations from nearby weeds – inkweed is a favoured host plant. The infestations are usually patchy and occur most frequently in late summer. The full-grown larvae are about 6 centimetres long and khaki-coloured, with two pairs of black marks on the upper surface of the body. They feed voraciously on foliage and fruit, and the foliage damage may be important in young plantations. On fruit, large caterpillars eat deeply into the flesh, while young ones gnaw only the rind.

The adult moths are about 5 centimetres across the outspread forewings, which are grey-brown to chocolate brown in the female and fawn to reddish brown in the male. They have a dark V-shaped marking on the anterior margin of the wing (Temperley, 1930).



Banana fruit caterpillar damage.

Control measures Poison bran bait of the type recommended for cutworms on page 222 under Bean Pests is sometimes effective when scattered in front of migrating caterpillars if they are advancing on a front. Carbaryl 0.1 per cent spray may be used when necessary.

DIPTERA

Queensland fruit fly *Dacus tryoni*

Although the fly will readily 'sting' and infest ripening bananas, it does not cause any damage under normal conditions of plantation management where fruit for market is harvested while it is 'hard-green'. 'Stinging' of green fruit in the plantation is unusual, but it may occur if there are prematurely ripening fruits in the bunch, for example, when fruits are weather-damaged or when they are affected by the condition cigar end.

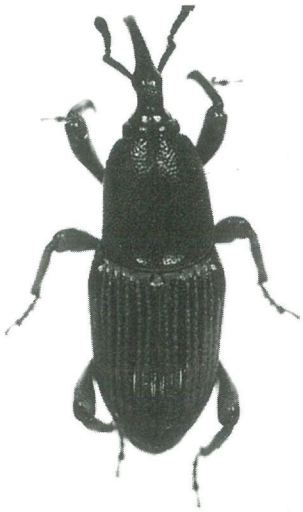
The small possibility of transport of fruit fly in bananas has led to restrictions requiring bananas for certain markets to be specially inspected or to be subjected to a fruit disinfestation treatment by dipping or fumigation. Dipping in dimethoate or fenthion is an efficient method of inhibiting the development of Queensland fruit fly larvae in bananas (Braithwaite, 1963). Neither material gives an undesirable flavour to the fruit, affects its appearance or presents any toxicity hazard to the consumer. Fumigation with ethylene dibromide also proved to be effective when studied at the Gosford Postharvest Laboratory in New South Wales. A system of bulk dipping bananas in dimethoate 0.03 per cent was practised initially for fruit entering the Murrumbidgee Irrigation Area, but now bananas are admitted there without treatment, provided that they are 'hard-green'.

Fruit fly infestation in the banana plantation is usually associated with poor plantation hygiene, such as ripening fruit left unharvested and attractive to the fly. Seedling summer fruits or tomatoes near the plantation may also be a source of infestation. In some seasons the Queensland fruit fly breeds in large numbers in wild fruits in the banana-growing districts. Some of these plant hosts are *Passiflora foetida, Ficus stephanocarpa, Ficus macrophylla, Davidsonia pruriens, Cyphomandra betacea, Cudrania javanensis* and *Cryptocarya rigida* (Anon, 1966).

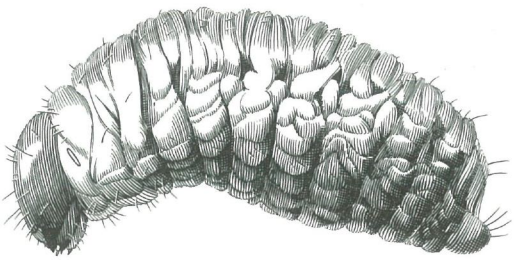
Control measures Control measures should be based on plantation hygiene – removing and destroying susceptible fruit. Spray baiting with maldison-protein hydrolysate bait, described on page 34 under Citrus Pests, will rapidly reduce the fly population. Once this has been done, baiting may be restricted to the margins of the planting, especially where they adjoin a bush area.

COLEOPTERA

Banana weevil borer *Cosmopolites sordidus*



Banana weevil borer. (Length about 12 mm)



Banana weevil borer larva. (Length about 12 mm)

Importance and Distribution This insect was recorded as black banana stem weevil in New South Wales in the Tweed River district by Froggatt (1919). According to McCarthy (1920), it was first seen here in 1916 and was probably introduced from Queensland where it had been known for 25 years. It has a widespread distribution in tropical areas.

Wallace (1937) concluded, as a result of a thorough survey on the North Coast, that the borer was not a serious pest of normal, established plantations and that its economic importance was often exaggerated. He stated that the best control measure was the provision of good growing conditions. Braithwaite (1963) conceded that the importance of weevil borer infestations is enhanced by poor culture, but showed (1958) that there was benefit in almost completely controlling weevil borers by using dieldrin, which was then highly effective for butt and ground spraying. The importance of banana weevil borers to banana growing remains controversial to this day.

Conditions for Infestation The climatic conditions most favourable to banana growth are also best suited to the weevil borer. A warm moist environment provides ample suitable food for the larvae, and allows breeding throughout the year.

Wallace (1937) studied the relative susceptibility of the different parts of the plant. Young spearpoint suckers and advanced tapered suckers are almost immune, although they are susceptible after removal for re-planting. Before the cutting of the bunch, stems are infrequently and lightly attacked. The parts which are seriously and rapidly attacked are spent stems whether they are cut or left standing, residual corms left after the stems have been cut, underground stubs of corm tissue left after unwanted suckers have been gouged out in de-suckering, any uprooted suckers or stems, and any corm or stem tissue which is large enough to be slow to dry.

Plants attacked Hosts of the weevil borer are plants of the genus *Musa*, including banana, plantain and Manilla hemp. It has also been found in sugar cane, but this has not been seen in New South Wales.

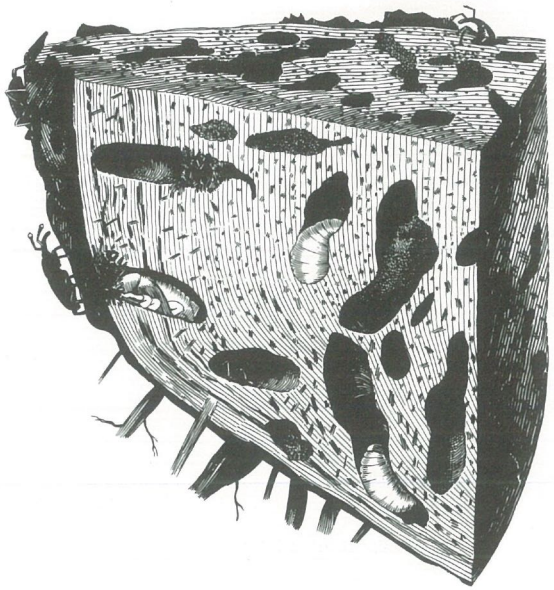
Description and Life History The weevil is about 12 millimetres long, elongate-oval, and hard-shelled with a pronounced snout. When newly emerged it is reddish brown, but after seven to ten days it becomes black in the moist interior of a banana corm. When dried it is dark grey. The wing covers and the thorax are covered with fine indentations. The egg is pure white, about 2 millimetres long and elongate-oval. The full-grown larva is about 12 millimetres long, creamy white with a brown head, stout, legless, curved, and swollen in the middle. The well-developed jaws of the larva are dark brown. The white pupa is about 12 millimetres long, and the structure of the future adult is clearly visible.

The nocturnal adults hide during the day around the base of the plant or between the leaf sheaths of the above-ground parts. They move at night to feed and lay eggs, but they are sluggish and will feign death if disturbed. The adults are long-lived. Egg-laying continues through the year but at a reduced rate in winter. Eggs are deposited singly in holes made in the plant by the female, the most favoured site being between the leaf-sheath scars on the crown of the corm, just above the ground. The eggs hatch in about eight days in summer and the larvae tunnel inwards. On reaching maturity, they work towards the surface of the corm and pupate in oval chambers. The average time from egg to adult is about 47 days, but it may be as short as 29 days in summer and up to six months in winter. Both males and females are produced, and fertilization is necessary for reproduction.

There are two periods each year when most adults emerge – September to November and March to May.

Injury The adults feed on the banana plant but the resulting damage is of no importance. The harm is done by the larvae as they tunnel in the corm or rootstock. The tunnels are circular and increase in size as the larvae grow until they are about 8 millimetres wide. The corm becomes riddled, and subsequent decay produces a blackened mass of rotting tissue which is deserted by the larvae. Another weevil, *Enteles vigorsi* Gyllenhal, is found in old corms and is similar in some ways to *Cosmopolites*, but it breeds in the rotten structureless tissue of the broken-down plant material.

In some cases weevil borer larvae may tunnel for more than 30 centimetres up into the stem. On a stem with a riddled corm, the leaves die prematurely. Grossly infested plants are easily pushed or blown over. Production from heavily infested plantations is low, as the small bunches bear only small bananas. Heavily infested plants are easily recognized, but where infestation is light the detection may be more difficult.



Banana corm damaged by banana weevil borer.

Dispersal While the weevils seem to have functional wings, it has not been proved that they can or do fly. Flight, if it does occur, is extremely rare. Weevil borer spreads from district to district or from one plantation to another mainly in infested corms or in other planting material. The adults can spread by crawling within the plantation and thence to adjoining plantations.

Control measures

NATURAL While natural enemies, such as rats, bandicoots, frogs, toads and perhaps birds, are known to prey on adults and fully grown larvae, no specific natural enemies seem to have any significant effect on the pest population. Braithwaite (1958) records the blue planarian worm, *Geoplana caerulea* Moseley, being found commonly sucking out the body juices of the weevil. The predatory hydrophilid beetle, *Dactylosternum hydrophiloides* Macleay, was introduced by CSIR, in cooperation with the Queensland Department of Agriculture and Stock, from Malaya in 1938 and 1939. It increased rapidly in southern coastal Queensland, and appears to have become established (Wilson, 1960). The New South Wales Department of Agriculture introduced the histerid beetle predator, *Plaesius javanus* Erichson, from Java in 1922 and from Fiji in 1934, but on neither occasion did it become established.

APPLIED Control of the banana weevil borer is compulsory under the *Plant Diseases Act, 1924 (as amended).* For new plantations, planting materials should be obtained only from plantations known to be free from the pest and should be examined carefully before planting.

Under the *Act* no person shall move any plant or any part of any plant, except the fruit, of the genus *Musa* into, or out of, or within, a quarantine area (which covers most of the commercial banana-growing districts in New South Wales) without a permit issued by the Department of Agriculture. As an additional precaution, planting material should be trimmed to remove roots, soil and leaf bases, and examined carefully. One or two slices should be taken from the material with a sharp knife and, if grubs or pupae are present, it should, of course, be destroyed.

Every owner or occupier of land within a quarantine area, on which any plant of the genus *Musa* infested with banana weevil borer is growing, must treat such a plant, and every plant forming part of the same stool, in the following manner:

(i) Cut off all spent stems of the plant not more than 30 centimetres above the level of the soil.
(ii) Deal with the removed portion of the spent stem so as to cause it to dry out rapidly.

Control of banana weevil borer with dieldrin reduced it from an abundant pest to extremely low levels in some areas, before the appearance of resistance. Where resistance to modern chemicals has not developed, plantations have been freed or almost freed from infestation, and maintained in that state for periods of up to two years (Braithwaite, 1958, 1963b, 1967). While dieldrin has given extremely satisfactory control, increased resistance to it in weevil borers has steadily become more widespread and caused alternatives to be found. Dieldrin resistance was first discovered on a few plantations in the Brunswick River district in 1968, and it had developed throughout the Brunswick, Tweed River and Richmond River districts by the late 1970s. In 1980, dieldrin was still effective in the Coffs Harbour and Nambucca districts.

In areas where banana weevil borer is still susceptible to cyclodiene insecticides, dieldrin 0.05 per cent or heptachlor 0.1 per cent should be applied at the rate of 600 millilitres per plant to the bases of the plants and suckers, and to the soil around the plants for a distance of 30 centimetres.

Dieldrin-resistant weevils can be controlled by treatment twice per year, at periods of maximum activity of adults (generally September to November and March to May), with pirimiphos-ethyl 0.18 per cent spray (750 millilitres per plant), or chlorpyrifos 0.25 per cent spray (600 millilitres per plant) or 5 per cent powder (30 grams per plant) (Wright, 1977).

African black beetle *Heteronychus arator*

These beetles sometimes seriously injure newly-planted banana suckers in land recently under paspalum pasture. A number of beetles may congregate at the base of the sucker and chew the tissue until it is ragged and looks like teased-out rope. The plants attacked will wilt, and may die or be severely retarded.

Details of the life history and control of African black beetle are given on page 295 under Tomato Pests and on page 284 under Potato Pests.

Monolepta beetle *Monolepta australis*

These small cream and red-spotted beetles swarm on to various crops in summer on the North Coast. Bananas are sometimes attacked, but not as frequently as some other crops. The young foliage and inflorescences are damaged. The behaviour of the swarms and methods of control are described on page 43 under Citrus Pests and on page 264 under Cucurbit Pests.

Banana rust thrips *Chaetanaphothrips signipennis*

Importance and Distribution Banana rust thrips is regarded as a serious pest in Queensland. In New South Wales it is not known further south than the Brunswick River district. It can cause considerable marking of fruit. Spraying with dieldrin to control banana weevil borer was followed by a marked reduction in damage by this thrips.

Conditions for Infestation This is a pest of warm humid climates in many tropical parts of the world. In Queensland it is much more damaging in the tropical north than it is in the south east, which suggests that it has already reached its southern limit.

Plants attacked Both citrus and cunjevoi, *Alocasia macrorrhiza*, as well as four other native plants have been recorded as hosts to rust thrips, but none is important in New South Wales. Banana plants are the only source of thrips in plantations (Braithwaite, 1963).

Description and Life History The adult thrips is yellow, about 1.3 millimetres long, and has two pairs of narrow fringed wings. Each forewing has two dark areas. The tiny eggs are laid in plant tissue under leaf sheaths or where two fruits touch. The eggs hatch in a little over a week and the white or yellow larvae reach their full size in another week. Then the larvae enter the soil to pupate. After a further seven to ten days the adults emerge. There are many generations per year, but greatest numbers are seen from November to March.

Injury Colonies feeding in the throats of the plants and beneath leaf sheaths may produce many areas of reddish tissue which are unimportant. The main injury is to the fruit and may be at points of contact between fruits or over the whole surface of fruit. If the young banana fruits are separated, small areas of skin, where the colonies of thrips are feeding, will show as smoky patches which later become rusty. A fruit which has been extensively attacked will develop a rough reddish brown surface which may crack if the damage is severe. Badly marked fruit is unsaleable, and if lightly marked is reduced in value.

Dispersal The adult thrips can fly, but it is unlikely that the pest is dispersed through flight. This species seeks cover in all stages; when disturbed, the adults hide as soon as possible. Transport to new areas is most likely to be in planting material. If this material cannot be obtained from thrips-free areas, it should be dipped in maldison 0.05 per cent until thoroughly wetted.

Control measures Spraying the bunches, stems (including the throats), bases of parent plants, suckers and adjoining soil with maldison 0.05 per cent at intervals of six weeks from November until March, or until the thrips become inactive, should prove to be effective.

Earlier recommendations also included the use of dieldrin 0.05 per cent, or lindane 0.03 per cent high-volume sprays, dieldrin misting, and dusts of dieldrin 1 per cent, or of lindane 1 per cent or of aldrin 2 per cent (Braithwaite, 1963, 1965). The decision to eliminate the use of cyclodiene insecticides wherever possible, and the development of resistance by banana weevil borer to dieldrin and lindane, have resulted in the withdrawal of these recommendations.

Dieldrin-treated fruit was of excellent appearance and generally of better market quality than fruit treated with other insecticides, for reasons which have not been clearly explained. The programme did not cause a build-up of strawberry spider mite and gave some protection against weevil borer.

Banana rust thrips damage.

Banana silvering thrips *Hercinothrips bicinctus*

Importance and Distribution This thrips causes occasional damage to banana fruit throughout the North Coast of New South Wales, and in southern Queensland (Anon, 1951). Infestation is generally patchy, but sometimes whole plantations are affected.

Conditions for Infestation Banana silvering thrips is most likely to cause trouble where weed growth is heavy or where choko or passion vines are allowed to grow amongst the bananas.

Plants attacked In addition to bananas and passion and choko vines, many weeds – such as cobbler's peg – are suitable hosts for this thrips.

Description and Life History The adult is slightly larger than the banana rust thrips, being about 1.5 millimetres in length. It is yellow to brown with a darker abdomen. Two brown bands mark the pale yellow hindwings. On the fruit the adults appear to be mainly black, with the folded wings making a pale yellow line along the entire body. The larvae are yellow-white, and usually have a small globule of black excrement on the tip of the abdomen.

The life history of this species is similar to that of the banana rust thrips, except that the silvering thrips appears in greatest abundance in spring and early summer.

Injury The only significant injury is to the fruit. After severe infestation the fruit develops a silvery discoloration speckled with dark thrips excreta, but patchy infestation sometimes produces a result similar to that from rust thrips. Deep longitudinal cracks in the fruit may also appear. Fruit at all stages of maturity is susceptible to attack.

Control measures Measures to control banana rust thrips are effective against the silvering thrips, but may have to be started in early spring. A careful watch should be kept on bunches in plantations known to be subject to attack by this thrips; both adults and larvae can easily be seen on the fruits. In addition, weed growth should be discouraged.

HEMIPTERA

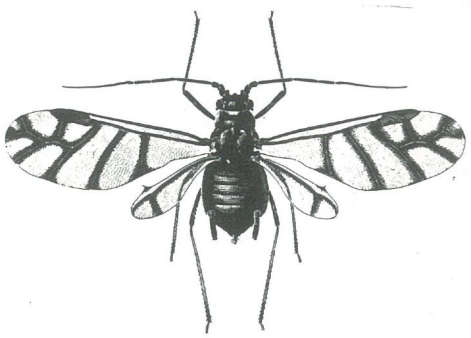
Banana aphid *Pentalonia nigronervosa*

Importance and Distribution The first record of banana aphid in New South Wales, in the Tweed River district, was published by Froggatt (1923), but it had undoubtedly been there for some years already. It has a world-wide distribution. The primary importance of this pest is as the only vector of the dreaded bunchy top virus disease; the association between this aphid and the disease was demonstrated by Magee (1927).

Plants attacked The known hosts of the banana aphid throughout the world, as listed by Zeck and Eastwood (1929), are *Musa* spp. – *M. cavendishii, M. sapientum* and *M. textilis* (Manilla hemp) – as well as *Strelitzia* sp., *Ravenala* sp., *Alpinia speciosa*, *A. rafflesiana* and *Arum maculatum.*

Description and Life History The banana aphid has no male forms and lays no eggs. All reproduction is by the birth of living young. The adult is about 1 millimetre long and reddish brown or dark brown, the younger forms being paler. Adults may be winged or wingless. The forewings have a peculiar venation quite unlike that of other aphids and the veins have dark borders on both the fore- and hindwings; the hindwings are very small (Zeck and Eastwood, 1929).

Aphid colonies are found around the bases of the pseudostems at and below soil level as well as on emerging suckers. Dense colonies are found behind the sheath of the outer leaf and the pseudostem, and along the midribs on the undersurfaces of leaves. The aphids breed very rapidly under favourable conditions in warm moist weather, and secrete a copious amount of honeydew which attracts ants. Large quantities of honeydew can accumulate around the pseudostem between the sheathing bases of the leaves and, when acted upon by yeasts, it forms a white slimy paste. Aphids feed and breed throughout the year, but the peak of activity is usually in late spring.



Banana aphid – winged adult. (Length about 1 mm)

Injury Gross feeding weakens the plant, and the honeydew and sooty mould spoil the appearance of the fruit, but by far the most destructive role of the aphid is as the only vector of bunchy top disease. The extremely successful control of that disease has been based on avoiding infection by eradicating all diseased plants, and by replanting only with material known to be clean. Occasional isolated outbreaks of bunchy top may occur in clean plantations as a result of the arrival of air-borne aphids.

Dispersal Aphids may move from place to place by flying or on infested plant material, the latter probably being the more important. Planting material, in accordance with the requirements of the *Plant Diseases Act, 1924 (as amended)*, should be closely examined and any suspicious-looking suckers discarded. In some areas, planting material is subjected to a hot water dip to eliminate eelworms. This treatment also kills banana aphid.

Control measures

NATURAL Many natural enemies prey on the banana aphid, including ladybird beetles, lacewing larvae, and the wasp parasite, *Aphidius* sp. All are hindered by the ants attracted to aphid honeydew. If ants are suppressed by spraying, there is a subsequent increase in predator activity and a decrease in aphid infestation. However, the level of control exercised by the natural enemies is not sufficient to remove the danger of disease transmission by the aphid.

APPLIED There is a legal obligation to suppress aphids where bunchy top is present. It is also desirable to control the insect because of its direct damage, especially in young plantations. Diazinon 0.025 per cent spray, or a systemic aphicide, sprayed on the plants or poured down the 'throats', will be effective.

Under the requirements of the *Plant Diseases Act, 1924 (as amended)*, plants or parts of plants, excepting the fruit, must not be moved out of or within a quarantine area, nor planted in it without a permit. Weeds must be removed to a distance of at least 2 metres around any plant of the genus *Musa* in any quarantine area, and if this has not been done for a period of six months, the plants must be destroyed.

Plants infected with bunchy top must be sprayed to kill all aphids, and banana plants within 5 metres of an infected plant must also be sprayed. The infected plants must be destroyed in a way that will prevent any regrowth and so that rapid death of all tissue will result.

Latania scale *Hemiberlesia lataniae*

The adult female scale has a dirty white circular cover which is 1.5 to 2 millimetres in diameter, with a light brown sub-central marking. The scale may be found occasionally on the skin of banana fruits or on bunch stalks. The male is smaller and more slender. Latania scale has a wide variety of hosts amongst subtropical plants. Infestation of bananas is of little importance.

Cyanophyllum scale *Hemiberlesia cyanophylli*

Heavy infestations of these scales on banana fruit has been seen, especially where the plants have been subjected to a heavy fungicidal spray programme. The adult female's scale cover is roughly oval or slightly triangular and 1 to 2 millimetres long. It is thin white and semi-transparent, and the insect's yellow body shows through, giving it a light brown appearance. The male is smaller and more elongate. Like the latania scale, it has little economic significance.

Cyanophyllum scale on banana.

ARACHNIDA ACARINA

Strawberry spider mite* *Tetranychus lambi*

Importance and Distribution Several species of spider mites have been reported on bananas, but *Tetranychus lambi* is the most important and may infest bananas wherever the crop is grown in New South Wales.

Moderate levels of infestation, which occur under the normal climatic conditions of dry spring and early summer followed by wet weather, can be tolerated except on the bunches covered in plastic. However, in dry years the infestation may reach a level which requires treatment due to the generally debilitating effect on the plants, especially in young plantations. Strawberry spider mite can thrive on plastic-covered bunches, causing surface injury to the fruit.

Conditions for Infestation In the hot dry weather which favours the mites, plantations supporting heavy growth of broad-leafed weeds are the ones most likely to suffer from this spider mite. Young plantations are most subject to attack as the circumstances in them are likely to suit the mites – the presence of weeds or catch crops and the comparative scarcity of natural enemies of the mites.

Description and Life History The adult spider mite may be straw-coloured or greenish. Colonies are formed on the undersurfaces of leaves, and much fine webbing is produced. Yellow or colourless eggs are scattered under the webbing. The development from egg to adult may take only a week.

Injury Infestation of banana plants suffering from water stress may be extremely damaging. Colonies form on the undersurfaces of leaves beside the midribs and spread out as they grow, causing yellow discoloration to appear on the upper surfaces. The whole undersurface may be russeted, the margins may wither and the whole leaf may dry prematurely, with consequent falling of heavily infested leaves. Leaf-fall may result in sunburn of bunches. If the mites infest bunches under the covers, they may cause severe blemishing of the fruit; the fruit skin may become dark red. The damage is spread evenly around the fruit and is therefore different from rust mite injury which is mainly between the fingers. Strawberry spider mite injury on bananas is usually worse around the stalk end of the fruit than at the flower end.

Control measures

NATURAL The small black mite-eating ladybird, *Stethorus vagans*, is an extremely effective predator of strawberry spider mite. Ladybird populations can build up quickly, and soon reduce the spider mite numbers to a low level.

Infestation can be reduced by keeping the plantation clear of weeds, and by controlling the spider mites on catch crops between the rows. Residues of such crops should be ploughed in or removed from the plantation.

APPLIED When direct treatment of bananas is necessary, tetradifon can be applied at the rate of 220 grams per hectare by either misting or aerial spraying. Misting is usually applied from shoulder-mounted misters.

A common practice for the treatment of plastic-covered bunches has been to nail a dichlorvos-impregnated plastic strip to the bunch at about one-third of the bunch length down from the top. The strip slowly releases the dichlorvos inside the plastic cover.

Damage by strawberry spider mite.

* Previously called banana spider mite.

Avocado pests

Avocados are grown on the Far North Coast of New South Wales, and are increasing in importance in the Sunraysia district in the Murray River area. This high-value crop is marketed mostly in Sydney or the southern States. As consumers demand a high-quality clean-skinned fruit, blemishes are rather important. Thus the control of scales, which are usually regarded as insignificant, may be necessary to meet the high standards required by the interstate market.

Monolepta beetle, fruit-spotting bug and Queensland fruit fly have long been recognized as important pests in the Far North Coast district as they cause skin-blemishes that down-grade the fruit offered for sale.

An account is given on pages 179 to 181 of the pests of avocado listed below.

ARTHROPODA

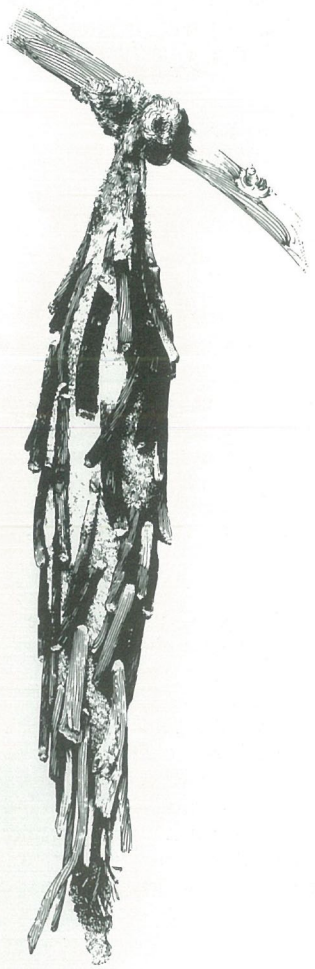
INSECTA	LEPIDOPTERA
Saunders' case moth	*Oiketicus elongatus* Saunders
	DIPTERA
Queensland fruit fly	*Dacus tryoni* (Froggatt)
	COLEOPTERA
Monolepta beetle	*Monolepta australis* (Jacoby)
Flea beetles	Halticinae
Brown leaf-eating beetle	*Rhyparida* sp.
	HEMIPTERA
Latania scale	*Hemiberlesia lataniae* (Signoret)
Fiorinia scale	*Fiorinia fioriniae* (Targioni-Tozzetti)
Spanish red scale	*Chrysomphalus dictyospermi* (Morgan)
Coon bug	*Oxycarenus arctatus* (Walker)
Fruit-spotting bug	*Amblypelta nitida* Stål

INSECTA LEPIDOPTERA

Saunders' case moth *Oiketicus elongatus*

Larvae of this moth sometimes cause damage by feeding on the leaves of avocados and making ragged holes. Only individual trees are attacked. The female moth lives in a case which may be up to 13 centimetres long. She is unable to fly and produces a large number of eggs. The young larvae hang on threads, and are spread by wind over a limited area. Large populations may sometimes feed on individual trees.

Control of a related species, leaf case moth, is discussed on page 26 under Citrus Pests.



Larval case of Saunders' case moth. (Length up to 13 cm)

DIPTERA

Queensland fruit fly *Dacus tryoni*

All varieties of avocado may be 'stung' by fruit fly, but maggot development is most common in thin-skinned varieties and seedling fruits. Maggots rarely develop in the usual commercial varieties, but a severe skin blemish is caused. 'Stinging' by fruit flies produces raised triangular-shaped cracks on the skin which are about 10 millimetres wide. Sap exudes through the crack and dries as a white residue that persists through ripening. A hard lump about the size of a pea forms immediately beneath the skin, and is firmly attached to it. This does not affect the edibility of the fruit. On the North Coast, the varieties Mexican Seedling, Habersham, Claude Walker and Early Eastwood have all been heavily infested by maggots in autumn.

Bait-spraying as described on page 173 for Banana Pests and page 34 for Citrus Pests should be effective in overcoming the problem.

COLEOPTERA

Monolepta beetle *Monolepta australis*

In the spring, swarms of these strongly-flying cream beetles, with red spots on the wing covers, commonly attack young growth and flowers of avocados, leaving the trees looking as though they had been scorched by fire. In the summer, further swarms may do considerable damage by grazing on the soft skins of the fruits.

This insect and its control are described on page 43 under Citrus Pests.

Avocados damaged by monolepta beetle. P.R.I., Dept of Ag. Vic.

Flea beetles Halticinae

These small hopping beetles sometimes feed heavily on nursery trees by chewing small holes in the leaves. Spraying with carbaryl 0.1 per cent should control them effectively.

Brown leaf-eating beetle *Rhyparida* sp.

This brown beetle is about 4 millimetres long, and sometimes appears in large numbers in summer-autumn. The beetles graze in swarms, causing severe blemishing of the fruits and skeletonizing the foliage. Spraying lightly over the swarms with carbaryl 0.1 per cent should control them.

HEMIPTERA

Latania scale *Hemiberlesia lataniae*
Fiorinia scale *Fiorinia fioriniae*
Spanish red scale *Chrysomphalus dictyospermi*

These three species of armoured scales may infest avocados, especially latania scale.

LATANIA SCALE The adult female's scale cover is circular, 1.5 to 2 millimetres in diameter, strongly convex and dirty white in colour. It has a large, pale brown, central to sub-central marking. The male is smaller and more slender.

Latania scale on avocado.

FIORINIA SCALE The adult female's scale cover is shield-shaped, 1 to 1.3 millimetres long, thin and yellowish brown to orange-brown. There is a pale yellow terminal marking.

SPANISH RED SCALE The adult female's scale cover is circular, 1.5 to 2 millimetres in diameter, slightly convex, and greyish brown with a clearly marked central ring. The male is smaller.

If these scales are numerous, they can inflict significant damage on trees. On the dark fruit, even a few scales show up as a prominent blemish. Some growers clean scales from the fruits by hand, but this is not practicable with rough-skinned varieties such as Haas. Natural enemies kill scales, but are not effective enough to protect the fruit from blemishing and down-grading.

Spraying in early summer with maldison plus petroleum oil, as described for California red scale on page 51 under Citrus Pests, would be effective.

Coon bug *Oxycarenus arctatus*

Large numbers of these small black and white bugs sometimes swarm on to the flowers, and may cause them to fall. They breed up in numbers on weeds and attack the fruit trees when conditions change and the weed growth matures or dries off.

Maldison 0.06 per cent spray will control coon bugs if applied so as to contact them.

Fruit-spotting bug *Amblypelta nitida*

These slender and usually pale green bugs are about 12 millimetres long. They cause a severe calloused blemish in the skin of the avocado, rather similar to that described above for Queensland fruit fly. When the damage is first observed, spraying with endosulfan 0.05 per cent or trichlorphon 0.1 per cent should be effective.

These bugs are described more fully on page 183 under Macadamia Pests.

Avocado damaged by fruit-spotting bug.

Macadamia pests

Macadamia in flower.

The macadamia or Queensland nut, a native of eastern Queensland and north-eastern New South Wales, has been improved under cultivation and selective breeding. Two species are grown commercially – *Macadamia tetraphylla* and *M. integrifolia*. The former has spiny leaves throughout its life and blossoms in the spring to produce an annual crop of nuts. The latter has smooth leaves, after the early seedling stage, and produces nuts through most of the year from two main blossoming periods – September-October and March-April. Nuts in both species are ripe about six months after blossoming. The flowers are produced in long drooping racemes, up to 30 centimetres in length.

Macadamia thrives best in the semi-tropics, being a rainforest tree requiring abundant moisture, but it is commonly grown in coastal situations which are far removed from the rainforest. Several insect pests, most of them native, attack the crop and can cause considerable damage.

An account is given on pages 182 to 184 of the pests of macadamia listed on the next page.

ARTHROPODA

INSECTA LEPIDOPTERA

Macadamia leaf miner	*Acrocercops chionosema* Turner
Macadamia flower caterpillar	*Homoeosoma vagella* Zeller
Macadamia nut borer	*Cryptophlebia ombrodelta* (Lower)
Macadamia twig girdler	*Neodrepta luteotactella* (Walker)

HEMIPTERA

Fruit-spotting bug	*Amblypelta nitida* Stal
Black citrus aphid	*Toxoptera citricidus* (Kirkaldy)
Macadamia felted coccid	*Eriococcus ironsidei* Williams

The following insects which are occasional pests of macadamia are described under sections on the pests of other crops on the pages listed below.

INSECTA LEPIDOPTERA

Orange fruit borer	*Isotenes miserana*	24
Yellow peach moth	*Dichocrocis punctiferalis*	128

INSECTA LEPIDOPTERA

Macadamia leaf miner *Acrocercops chionosema*

The adult is a small brown and silvery white moth, the larvae of which mine in the young tender foliage. Heavy infestations can retard growth considerably, especially of young trees. The tiny glistening white eggs are laid on the very young foliage. The yellow larvae produce twisting white tracks under the epidermis. Later these become prominent blister-like patches and, as the larvae grow, the whole surface of the leaf may become blistered. The shoot may die back. The full-fed larvae pupate in dead foliage on the tree or in leaf debris on the ground. Several generations are produced in a year.

Control measures Spraying new growth flushes with endosulfan 0.075 per cent is effective when young trees are attacked.

Macadamia leaf miner damage.

Macadamia flower caterpillar *Homoeosoma vagella*

These larvae sometimes destroy many of the flowers. The grey moths, which measure up to 15 millimetres across the outspread wings, lay their eggs on the inflorescence, usually on racemes bearing unopened buds. The egg is oval, flattened and has a pitted surface; it is white at first then turns yellow. The young larvae feed at first on the internal parts of the unopened buds, but later they feed more generally from within the protection of silken tubes with which they web together the buds and flowers on the raceme. When mature, they are about 10 millimetres long and very active. They quickly withdraw into their tunnels when disturbed, or they may fall and hang by a thread. They are brown above and yellow-green below. They usually pupate amongst debris at the base of the tree or in the angles of limbs. This caterpillar also commonly feeds on several species of *Grevillea*.

Control measures Two applications of endosulfan 0.05 per cent during the flowering period give satisfactory control.

Macadamia nut borer *Cryptophlebia ombrodelta*

Damage by this pest is usually not noticed until the nuts approach maturity and the hulls begin to split. The sawdust-like frass then becomes apparent amongst the clusters of nuts. Often the injury is not suspected until after harvest when some nuts are seen to have small holes in the shells and the kernels are found to have been destroyed. Other nuts may have no external sign, but will have a grub in the kernel. The time required to grade such a crop may be very costly.

The moths are active when the young fruits are beginning to develop. They are about 2.5 centimetres across the outspread wings, and pinkish brown with a dark brown blotch on the hind margin of each forewing. The flat circular eggs are deposited on the young growth of the flowering spike or on the soft husk of the developing fruit. The small larva bores into the young fruit and feeds on the kernel. The full-grown larva is yellow-brown with a pink stripe along the back and green spots on each body segment. To pupate, it forms a silken cocoon just below the outer surface of the fruit. When the moth leaves the pupal case, it pushes its way through the thin membrane in the shell of the fruit which was left by the caterpillar when it ate through most of the thickness before pupation. This caterpillar also attacks the seed pods of *Cassia* sp., *Acacia* spp. and *Bauhinia* sp.

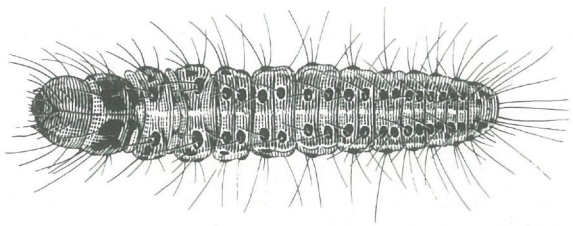
Control measures Control may be achieved by spraying during the fruit-setting period with carbaryl 0.1 per cent and two or three treatments may be required.

Macadamia twig girdler *Neodrepta luteotactella*

The larvae of this moth, which also commonly attack the waratah, are sometimes important as macadamia pests, especially of young trees. Two types of injury have been described (Wallace, 1936). In the first type, the larva chews the bark in the axil at the junction of a stem and a leaf, and may ringbark the branch or twig. The exposed ring is usually about 6 millimetres wide, but sometimes the twig may be stripped for as much as 4 centimetres. This type of damage may be very injurious to young trees.

The second type of injury is inflicted when the caterpillars destroy the leaf tissue from beneath the cover of a sheath of silken webbing, particularly on the basal halves. The leaves may also be webbed together in clusters, with brown pelletted frass entangled in the webbing. This mass of silk and excrement often remains long after the caterpillar has pupated and the moth has emerged. Sometimes the caterpillars graze on the husks of the fruit.

The yellow eggs are laid on the foliage and their appearance has been described as resembling corn-on-the-cob. When full-grown the caterpillars are nearly 2.5 centimetres long and mottled brown, with rows of dark brown spots on the back and one or two bristles rising from each spot. The head is dark brown and strongly chitinized. The larva pupates in the webbing, and a handsome pure white moth, about 2.5 centimetres across the outspread wings, emerges in due course. The legs, antennae and proboscis are yellow. Several generations occur in the year, but young larvae are most abundant in spring and summer.



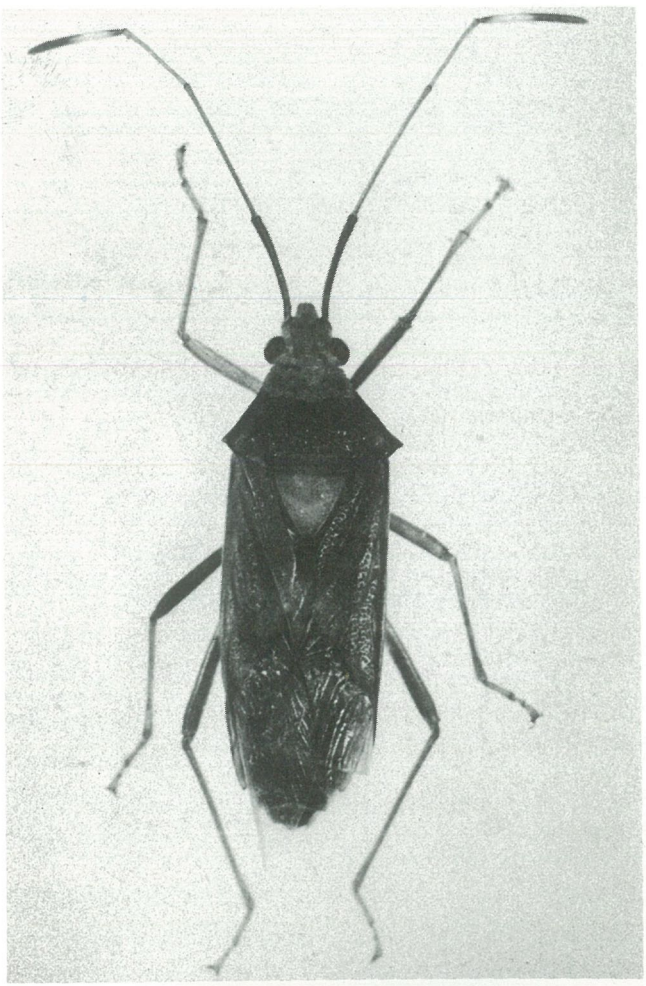
Macadamia twig girdler caterpillar. (Length, when fully developed, about 2.5 cm)

Control measures Control by spraying with endosulfan 0.07 per cent or carbaryl 0.1 per cent is effective.

HEMIPTERA

Fruit-spotting bug *Amblypelta nitida*

These slender bugs attack a variety of crops – macadamias, avocados and stone fruits in New South Wales and citrus, mangoes, custard apples, pineapples, granadillas, passionfruit, cotton and various beans in Queensland (Anon, 1961). They attack the young macadamia nuts soon after setting and cause many to drop. The most important effect, however, is to cause



Fruit-spotting bug. (Length about 12 mm)

kernel malformation. The bugs are not easily found on the trees, nor do they infest all trees in the planting. The first indication of their activity is often the malformation and brown spotting of the kernels when mature nuts are cracked.

The life history of this bug in Queensland has been described by Brimblecombe (1948). The pale green egg is oval and about 1.5 millimetres long. Eggs are laid singly on the young foliage and on the developing nuts in spring and summer. The pear-shaped wingless nymphs are green, with two dark spots on the abdomen, and develop into slender pale green, winged adults about 12 millimetres long. The time elapsed from egg-laying to adult is five or six weeks. There are three generations per year, and the adults produced in autumn overwinter and lay eggs in spring. Considerable injury can result from the presence of only small numbers of bugs at the time of fruit setting.

Control measures Endosulfan 0.05 per cent or trichlorphon 0.05 per cent spray at flowering will control the fruit-spotting bug. One or two follow-up sprays might be necessary as bugs may still migrate on to the trees while the young nuts are susceptible to injury.

Black citrus aphid *Toxoptera citricidus*

Clusters of small shining black aphids, both winged and wingless, infest young leaves and shoots of macadamia in spring and again in autumn. They cause the shoots to wilt and may seriously retard the growth of young trees. Considerable honeydew attracts swarms of ants, and sooty mould growing on it blackens the plants.

For control on young trees see page 69 under Citrus Pests.

Macadamia felted coccid *Eriococcus ironsidei*

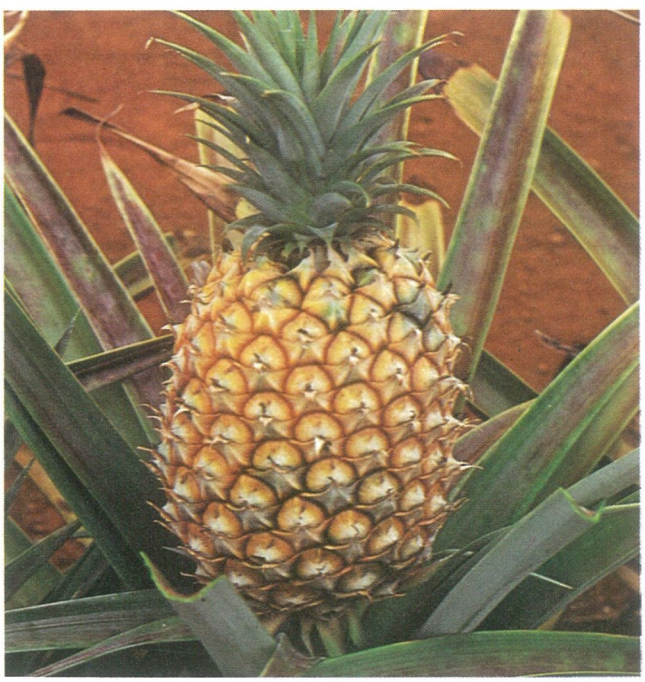
This scale insect occurs widely in south-eastern Queensland (Ironside, 1973), and is also present in northern New South Wales. The adult female is about 1 millimetre long and is enclosed in a white-to-yellowish felted sac.

Large numbers of oval yellow-green soft scales infest the upper and lower surfaces of leaves and settle along the veins. They secrete copious quantities of honeydew which attracts ants, and encourages a heavy growth of sooty mould which blackens the foliage and retards the growth of young trees. There is severe distortion of young shoots or flower racemes, and infested parts are stunted and often die.

Control measures These should be aimed at reducing the spread of the pest. Trees which are heavily infested in the nursery should be destroyed and the remainder sprayed thoroughly three times, at three- to four-week intervals, with petroleum oil 1 per cent. On established trees, spraying with petroleum oil 1 per cent at flowering will reduce damage.

Pineapple pests

Pineapples are grown commercially in New South Wales in small areas along the coast from the Queensland border to as far south as Port Macquarie. Most of the production is for fresh fruit. Not many insect pests require control measures, the most important being pasture white grubs, *Rhopaea* spp., pineapple scale, *Diaspis bromeliae* (Kerner), and pineapple mealybug, *Dysmicoccus brevipes* (Cockerell). They are generally of limited importance when considered alone, but they may contribute to a complex condition known as 'pineapple decline'.



Pasture white grubs *Rhopaea* spp.

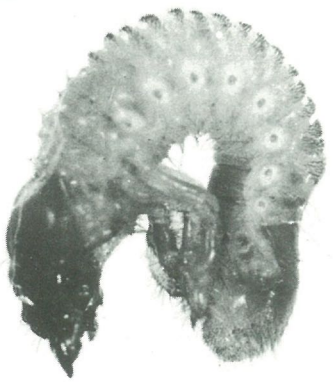
Pasture white grubs, more often called 'white curl grubs', are common, especially in the red volcanic soils of some coastal districts. They feed on a variety of hosts, such as pasture plants and sugar cane. When land carrying pasture, especially of paspalum, is ploughed up and prepared for a crop like pineapples, it is sure to contain some of these grubs. The roots of the pineapples are chewed, but the most conspicuous damage is channelling and scoring of the butts or rhizomes of the plants by the grubs. Plants so attacked become yellow and stunted. As they are almost without roots, they can easily be pushed over.

Pineapple decline can probably be attributed mainly to soil nematodes, and damage done by the grubs is often aggravated by these eelworms. In the absence of nematode attack, the plants seem to be capable of tolerating some injury by the grubs. It has been shown that pre-planting fumigation of the soil with ethylene dibromide, plus subsequent annual fumigation with dibromochloropropane, prevents significant nematode infestation of the roots. The success of the treatment was reflected in greater vigour and higher yield from fumigated plots when compared with non-fumigated plots, even though white curl grub damage was evident in all plots and severe in most plants. Soil treatment with DDT-parathion was not effective in preventing attack by pasture white grubs on a long-term basis (Anon, 1968).

Pasture white grubs are immature stages of large brown Christmas beetles that emerge from the soil in early summer. The females lay eggs in the soil, and the larvae remain in the soil for two years feeding on roots and other organic matter. When full-grown they are about 4 centimetres long and 8 millimetres thick, and dirty white with a brown head. The body is characteristically curled, but when the grub is exposed it can crawl actively. These larvae are voracious feeders and move from plant to plant. The infestation tends to move outwards from a central spot where the eggs were laid.

Damage is likely to be severe in young plants set out in ground that has been under grass for some years; large grubs, deprived of the grass by ploughing, move directly to the young pineapples. Older pineapples can tolerate some injury.

Control measures Control should be based on thorough preparation of the land by fallowing to starve the grubs. Insecticidal treatments before planting are not sufficiently effective to be recommended.



A pasture white grub.

Pineapple scale *Diaspis bromeliae*

This is an introduced armoured scale that sometimes occurs in dense colonies on sheltered parts of the pineapple plant. The female is about 2 millimetres across, circular, flat and greyish white. The male is oblong and almost white, with three longitudinal ridges on its upper surface. The males are found mostly at the bases of the fruits and on young suckers, but the females are mainly on the leaves (Jarvis, 1944). The female deposits eggs under her body. The young scales hatch and wander over the plant before settling in their permanent positions. Development to adult takes about two months in the warmer months, and there are several generations per year. Heavily infested foliage appears to be covered by a grey scurf and the plants become weak and stunted, and may produce undersized fruits. Infestation is usually heaviest in ratoon fields, and on fruits and suckers shaded by foliage. It is most pronounced on ground suckers in the centres of rows where light penetration is poor.

Control measures Adequate control may be achieved by removing and burning the infested plants when they are first noticed. Spraying with petroleum oil 2 per cent may be effective if it is done thoroughly and the spray is directed well into the bases of the plants, but this is rarely warranted. The use of residual sprays should be avoided as natural enemies, such as ladybirds and a wasp parasite *Aphytis* sp. exercise a check on the population, and nothing should be done which would interfere with this natural control (Brimblecombe, 1955).

Pineapple mealybug *Dysmicoccus brevipes*

These insects are held responsible for a disease condition, pineapple wilt, which is believed to be induced by toxic substances injected into the pineapple plant by the mealybug when feeding. The condition is important in other countries, but in New South Wales mealybugs have been pests of only minor importance. They are small, white, oval, soft-bodied sucking insects found mainly in sheltered parts of the plants, such as on the bases of fruits and in the axils of leaves, although they are sometimes found on the rhizomes. The infested areas become covered with white mealy material derived from the waxy substance covering the bugs. About three generations are produced per year, and the adults give birth to 50 to 100 young.

Control measures Control is seldom warranted. Spraying thoroughly in summer-autumn with maldison 0.1 per cent plus 1 per cent petroleum oil is effective in the control of mealybugs when necessary.

Passionfruit pests

Commercial passionfruit growing in New South Wales is confined mainly to the North Coast. The plants grow luxuriantly under the subtropical conditions, but they do tend to run to vegetative growth at the expense of fruiting, and they are likely to suffer severely from the fungus disease brown spot. The most suitable conditions for growth will be found in frost-free locations with air movement, but protected from westerly and southerly winds. The area should be open to the north. Good drainage is important but soil quality is less so. Fertilizing compensates for deficiencies and allows control of vine growth.

Passionfruit is grown for the fresh fruit market and for processing. Most commercially-grown passionfruit plants are Queensland hybrids which produce throughout the year.

All plants must receive thorough and regular sprayings with fungicides to control brown spot.

There are no insect or mite pests specific to the cultivated passion vine, but the crop may suffer from attack by populations bred up on other nearby plants.

An account is given on pages 187 to 190 of the pests of passionfruit listed below.

ARTHROPODA

INSECTA

DIPTERA

Queensland fruit fly	*Dacus tryoni* (Froggatt)
A leaf-miner	Agromyzidae

COLEOPTERA

Fuller's rose weevil	*Asynonychus cervinus* (Boheman)
White striped weevil	*Perperus lateralis* Boisduval
Ground weevil	*Mandalotus* sp.
African black beetle	*Heteronychus arator* (Fabricius)
Monolepta beetle	*Monolepta australis* (Jacoby)
Fig longicorn	*Dihammus vastator* (Newman)

THYSANOPTERA

Greenhouse thrips	*Heliothrips haemorrhoidalis* (Bouché)

HEMIPTERA

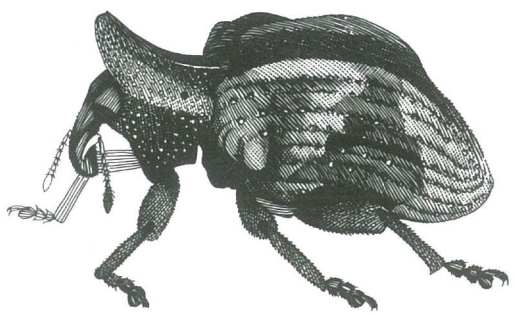
Green vegetable bug	*Nezara viridula* (Linnaeus)
Rutherglen bug	*Nysius vinitor* Bergroth
Passionvine hopper	*Scolypopa australis* (Walker)
Green mirid	*Creontiades dilutus* (Stål)
Black scale	*Saissetia oleae* (Olivier)
Soft brown scale	*Coccus hesperidum* Linnaeus
Passionvine bug	*Leptoglossus australis* (Fabricius)
Mealybugs	Pseudococcidae

ARACHNIDA

ACARINA

Passionvine mite	*Brevipalpus phoenicis* (Geijskes)

In addition, occasional injury is caused to passionfruit vines by termites, Isoptera, which are described on page 286 under Potato Pests, and by the larvae of painted apple moth, *Teia anartoides* Walker, which is described on page 99 under Apple Pests. Grubs of a weevil, *Oemethylus triangularis* Lea, feed on the fruit of the native passion vine, *Passiflora herbertiana*, but have not been recorded from cultivated varieties.



The weevil *Oemethylus triangularis* which feeds on a native passion vine. (Length about 12 mm)

INSECTA DIPTERA

Queensland fruit fly *Dacus tryoni*

Fruit flies sometimes cause considerable passionfruit loss in New South Wales North Coast plantations in spring and summer. The flies 'sting' young green fruits and the attack produces boil-like swellings with the puncture in the centre. Very young fruit attacked in this way will usually shrivel and fall. Older fruit will continue to hang, and may grow to maturity. These swellings are the result of growth stimulation in the corky tissue around the puncture. Maggot development in the fruit is rare, but it happens occasionally in thin-skinned fruits. In these cases, the maggots may reach the full-fed stage and pupate inside the fruit, but the emerging flies are imprisoned within the hard rind and die.

Control measures Spray-baiting with maldison–protein hydrolysate bait, begun when fly attack is first seen or anticipated and continued at regular intervals, will give good control, provided that the pressure of large fly populations from nearby breeding sources is not too great. Twice-weekly applications may be required if the flies are extremely numerous. The fruit should be avoided when bait spraying.

Fruit fly and its control measures are discussed more fully on page 31 under Citrus Pests.

Queensland fruit fly damage to passionfruit.

Cross section of passionfruit damaged by Queensland fruit fly.

A leaf-miner Agromyzidae

Larvae of an unidentified agromyzid fly have occasionally been seen tunnelling in the leaves of young passion vines. Heavy infestation can stunt the growth of young plants but has not been seen to harm older plants.

Large numbers of a small chalcid wasp have been bred from infested leaves, and it is likely that the pest is kept in satisfactory check by these. No artificial control has been found to be necessary.

COLEOPTERA

Fuller's rose weevil *Asynonychus cervinus*

This brownish grey weevil is about 8 millimetres long, and can do considerable damage to passion vines. The weevils eat the edges of the leaves, producing a saw-tooth effect. The damage is done during summer and autumn, and may severely restrict growth especially if the plants are just climbing up to the wires. The weevils feed at night, but they can usually be found during the day clustered among the foliage or in the growing tips. They do not attack the fruit.

Control measures Spraying with carbaryl 0.1 per cent in the summer–autumn period is effective in controlling this pest.

White striped weevil *Perperus lateralis*

These small light grey weevils are about 6 millimetres long, and have a white stripe along the length of each wing cover. They have been troublesome in the spring months in the high districts near Gosford. They first became obvious in August and were most active in September and October, but had usually declined in activity before the beginning of November. They fed at night by gnawing the growing tips, thus seriously retarding growth particularly of young vines. They also fed to a lesser extent on the green bark of the main stem.

Further details are given on page 40 under Citrus Pests.

Ground weevil *Mandalotus* sp.

These small grey-brown weevils are about 3 millimetres long, and can cause considerable harm to newly-planted passionfruit vines in early summer. They chew the young shoots and leaves at night, and can halt growth. As the new plants are often covered with brush to prevent scorch and to reduce transpiration and evaporation, the damage may be very advanced before it is noticed. The adult weevils shelter in the soil by day, and remain quite motionless when disturbed.

Control measures Spraying carbaryl 0.1 per cent over the plants and the soil around them at transplanting should give good control.

African black beetle *Heteronychus arator*

Newly-planted passionfruit vines may be attacked by black beetles in spring or autumn. Only the newly-set plants are attacked; once established, the plants will not be susceptible. When plants wilt suddenly, the base of the stem at ground level and below is found to have been chewed roughly and teased. Usually the beetles are found near the damaged plant. If they have moved away, proof of their recent presence will be conclusive if the chewed bark looks like frayed rope.

Control measures New plants, or replacement plants for those that have been damaged, should be jetted with DDT 0.1 per cent around their bases.

African black beetle is described more fully on page 295 under Tomato Pests.

Monolepta beetle *Monolepta australis*

These 6-millimetre-long beetles are creamy yellow with red shoulders, and sometimes swarm on passion vines during spring or summer on the North Coast. They may cause considerable injury by eating leaves and shoots, and may eat the surface of green fruits. The beetles feed on plants in swarms which often concentrate on some vines and leave others alone, and the same field may be subjected to a series of attacks. Where the beetles come from is not known.

Control measures Contact spraying with carbaryl 0.1 per cent should achieve satisfactory results if applied twice or more, depending upon the intensity of attack.

Monolepta beetle is discussed in greater detail on page 43 under Citrus Pests.

Fig longicorn *Dihammus vastator*

Longicorn beetle larvae tunnelling in the stems of passion vines near Gosford were described by Froggatt (1919). Many old vines had single larvae in the stems, but sometimes four or five in a swollen root base. These insects have a wide host range.

A more complete account of this insect is given on page 195 under Fig Pests.

THYSANOPTERA

Greenhouse thrips *Heliothrips haemorrhoidalis*

Greenhouse thrips have sometimes caused severe damage in late summer to the foliage and to fruits in contact with leaves on heavily-foliaged vines in protected situations. The leaves take on a leaden grey coloration as a result of heavy feeding by the thrips on the undersurfaces. They are also marked by deposits of the black tarry excrement from the thrips. Many leaves turn brown and fall. The fruit surfaces will be blemished in the same way.

Greenhouse thrips is described more fully on page 43 under Citrus Pests.

HEMIPTERA

Green vegetable bug *Nezara viridula*

The green shield-shaped adults and parti-coloured – red, green, black and orange – nymphs have not been important as pests since the introduction of egg parasites for their natural control many years ago. The bugs suck the sap of young green fruits and, if numerous, cause the fruit to fall.

Details of this pest are given on page 232 under Bean Pests.

Rutherglen bug *Nysius vinitor*

These small, grey, silver-winged native bugs sometimes swarm on passion vines, especially if the vines are near weedy areas where the bugs have bred up in the spring. Large numbers of the winged adults or wingless nymphs on the stems and foliage can kill the plants. Another type of injury by this bug is when fruits up to the size of walnuts, or even larger, wilt and possibly fall. This is caused by the bugs clustering on the fruit stalk, hidden at first by the dried-up floral parts that form a collar around it. Water stress may also cause young green fruits to shrivel, so a thorough examination of the situation should be made before action is taken.

Rutherglen bug is described in greater detail on page 163 under Grape Pests.

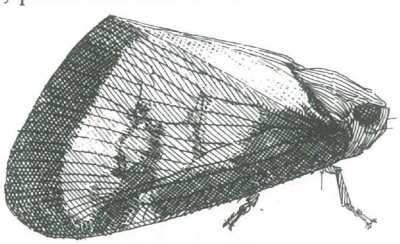
Passionvine hopper *Scolypopa australis*

These native bugs attack many hosts and may injure passion vines grown in the home garden. They rarely do much damage to commercial crops. Adults and nymphs cluster on the stems and along the mid-veins of the leaves where they suck the sap. They produce a colourless honeydew that falls on the foliage and supports a growth of sooty mould fungus. Heavy infestation causes wilting of the leaves with some yellowing and leaf-fall. The young green fruit may also shrivel and fall when the bugs feed on the fruit stalks. When they do this they concentrate on the stalk above the floral collar, whereas Rutherglen bugs would be under the collar.

The adults are about 8 millimetres long and superficially resemble small moths in appearance. Viewed from the side they are roughly triangular. Their bodies are brown, and the wings have mottled brown and clear areas. The wings extend beyond the body, and are often laid out flat over the body when the bugs feed. These robust insects hop or fly when disturbed. The females lay their elongate-oval eggs in slits cut into the bark of thin shoots and twigs, and sometimes in the tendrils, of the passionfruit plants.

The young nymphs are squat, greenish brown and horny, and carry woolly white filaments like tail feathers at the tip of the abdomen. They are very alert and hop readily when disturbed. Although several generations have been claimed to be produced in a year in tropical fruit-growing areas there is evidence that only one generation per year is produced on the Central Coast of New South Wales; the first adults usually appear in November or December.

Passionvine hoppers also attack many other cultivated plants and weeds. They are frequently seen on grapes, citrus and peach trees, beans, privet and bracken fern.



Passionvine hopper. (Length about 8 mm)

Control measures Infestations vary greatly from season to season. No doubt natural enemies play an important part in control. Cumber (1967) has described the role played by the egg wasp parasite, *Centrodora scolypopae* Valentine, and by another parasite and a predator.

Control by spraying is not easy. The insects are difficult to hit and wet with the spray because they are so active. It is necessary to spray the infested plant and then the ground underneath it, as many of the hoppers will have dropped. Unless they are wetted, the hoppers will re-infest the plant. Dimethoate 0.03 per cent plus petroleum oil 1 per cent is recommended for this treatment.

Green mirid *Creontiades dilutus*

This slender active pale green plant bug is about 6 millimetres long, and feeds on a variety of crop plants in the coastal region – in some years it does considerable damage to beans in the spring. On passion vines these bugs can be troublesome, especially in young plantings during late spring and summer. They suck the sap of the terminal shoots which arrests their growth. When the growing point is sucked out, the central tissue becomes yellow and dry, and eventually falls out. It may take some weeks for growth to be resumed from lateral buds; if attack is continuous and these lateral tips are destroyed, the plants are very severely checked. Young plants may not be able to reach the top of the trellis and the wires provided for them before the onset of winter.

If damage is suspected, a careful search of the tip growth will usually reveal the presence of the bugs, but characteristically they are never found in great numbers.

Control measures If control is necessary, action should be taken promptly. Much damage can be done in a short time, and recovery is relatively slow. Spraying with maldison 0.075 per cent or mevinphos 0.07 per cent would be effective in giving protection. Because of the high toxicity of mevinphos, great care must be exercised when using it.

Green mirid is described more fully on page 231 under Bean Pests.

Black scale *Saissetia oleae*

This scale is common on passion vines and is sometimes quite important on commercial crops. This is likely to be so when the passion vines are grown between rows of young citrus trees. On the vines, the scales cluster along the stems and the main veins on the leaves, especially on the undersurfaces. They produce copious honeydew and, therefore, sooty mould. Heavy infestation is quite damaging to the vine. Small black ants attend the scales.

Control measures Many natural enemies help to keep this scale in check, as described on page 63 under Citrus Pests. If applied control is necessary, carbaryl 0.05 per cent plus petroleum oil 1 per cent has been found to be effective. The use of

oil sprays on passionfruit is only recommended at low concentrations as the vines are susceptible to damage. If the spray is used, it should only be when the young scales are at their most numerous. This is often indicated by maximum ant activity. The ant population should be suppressed by butt spraying of the vines with chlordane.

The pest is described more fully on page 61 under Citrus Pests.

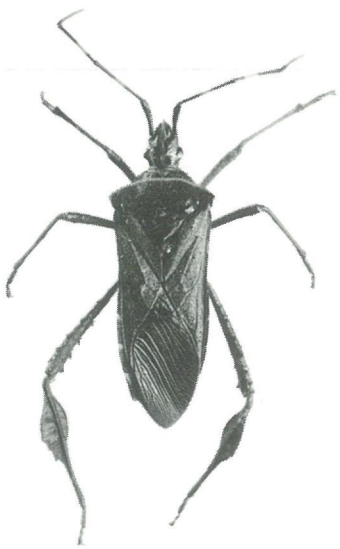
Soft brown scale *Coccus hesperidum*

Individual vines may sometimes be heavily infested by soft brown scales clustering along the leaf and fruit stalks, and along the main veins of the leaves. They produce copious honeydew which encourages dense sooty mould growth and attracts ants.

The measures recommended above for the control of black scale are also effective against soft brown scale.

Passionvine bug *Leptoglossus australis*

This elongated bug is 18 millimetres long, and dull black with a transverse red band behind the head and several red spots on the underside of the body. It feeds on many plants; in Queensland these include passionfruit, citrus and cucurbits. On the Far North Coast of New South Wales it attacks passionfruit by piercing the developing green fruits. Endosulfan 0.05 per cent spray is recommended for control.



Passionvine bug. (Length about 18 mm)

Mealybugs Pseudococcidae

Mealybugs sometimes cluster thickly on the fruit stalks of passion vines, where they shelter under the dried-up floral collar. Their clear honeydew falls over the fruit and produces sooty mould. This can be an important blemish on fruit grown for the fresh fruit market. The insects have also been blamed for causing some shrivelling of the young fruit, but this relationship has not been proved.

It is seldom necessary to spray to control mealybugs on passion vines.

ARACHNIDA ACARINA

Passionvine mite *Brevipalpus phoenicis*

In Queensland, Sloan (1946) recorded that this mite caused fruit and stem marking of passionfruit, gave the plants an unthrifty appearance, and even killed some of them. It has been recorded on the North Coast of New South Wales.

The sluggish mites are reddish brown, 0.25 millimetre long, and lie very flat on the plant surface. The oval eggs are bright red, and are scattered about in ones and twos over the plant surface amongst the mite colonies.

Control measures It is expected that dicofol 0.05 per cent will control these mites.

References

Anon (1951). *The Queensland Agricultural and Pastoral Handbook. Vol. III Insect Pests and Diseases of Plants*. Government Printer, Brisbane. 560pp.

Anon (1966). Queensland fruit fly. *Annual Report Entomology Branch, Department of Agriculture, New South Wales*, p.25. Sydney.

Anon (1967). Pineapple decline. *Annual Report Entomology Branch, Department of Agriculture, New South Wales*, p.21. Sydney.

Braithwaite, B. M. (1958). Ground spray treatments for the control of banana beetle borer (*Cosmopolites sordidus* Germ.) *Journal of the Australian Institute of Agricultural Science* **24:** 27-34.

Braithwaite, B. M. (1963). The sterilization of banana fruit against Queensland fruit fly (*Strumeta tryoni*). *Australian Journal of Experimental Agriculture and Animal Husbandry* **3**: 98-100.

Braithwaite, B. M. (1963). The banana beetle borer. *Agricultural Gazette of New South Wales* **74**: 396-9, 419.

Braithwaite, B. M. (1963). Banana rust thrips (*Scirtothrips signipennis* Bagn.) *Agricultural Gazette of New South Wales* **74**: 452-5.

Braithwaite, B. M. (1965). Control of banana rust thrips (*Scirtothrips signipennis* Bagn.) *Agricultural Gazette of New South Wales* **76**: 115-19.

Braithwaite, B. M. (1967). Banana beetle borer control investigations on

the North Coast of New South Wales. *Agricultural Gazette of New South Wales* **78**: 359–65.

Brimblecombe, A. R. (1948). Fruit-spotting bug as a pest of the macadamia or Queensland nut. *Queensland Agricultural Journal* **67**: 206–11.

Brimblecombe, A. R. (1955). Pineapple scale investigation. *Queensland Journal of Agricultural Science* **12**: 81–94.

Cumber, R. A. (1967). Factors influencing egg survival of *Scolypopa australis* Walker (Hemiptera-Homoptera:Ricaniidae) in the Sydney area (N.S.W., Australia). *New Zealand Journal of Science* **10**: 639–43.

Froggatt, W. W. (1919). The passion vine longicorn beetle. *Agricultural Gazette of New South Wales* **30**: 37–9.

Froggatt, W. W. (1919). The black banana stem weevil (*Cosmopolites sordidus* Germ.). *Agricultural Gazette of New South Wales* **30**: 815–18.

Froggatt, W. W. (1923). The banana aphis (*Pentalonia nigronervosa* Coquerel). *Agricultural Gazette of New South Wales* **34**: 296–7.

Ironside, D. A. (1973). Insect pests of macadamia. *Queensland Agricultural Journal* **99:** 241–50.

Jarvis, H. (1944). Pineapple scale. *Queensland Agricultural Journal* **59**: 26–9.

McCarthy, T. (1920). Banana root borer (*Cosmopolites sordidus* Germar). *Agricultural Gazette of New South Wales* **31**: 865–72.

Magee, C. J. (1927). *Investigation on the Bunchy Top Disease of the Banana.* Commonwealth of Australia Council for Scientific and Industrial Research Bulletin No. 30. H. J. Green, Government Printer, Melbourne. 64pp.

Sloan, W. J. S. (1946). Passion fruit mite. *Queensland Agricultural Journal* **63**: 145–7.

Temperley, M. E. (1930). Life history notes on the banana fruit-eating caterpillar (*Tiracola plagiata* Walk.) *Queensland Agricultural Journal* **33**: 251–61.

Wallace, C. R. (1936). Twig girdler moth of Australian nut trees. *Agricultural Gazette of New South Wales* **47**: 566–8.

Wallace, C. R. (1937). The banana beetle borer. Investigations and control measures. *Agricultural Gazette of New South Wales* **48**: 621–3, 638.

Wilson, F. (1960). *A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea.* Technical Communication No. 1, Commonwealth Institute of Biological Control, Ottawa, Canada. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England. 102pp.

Wright, W. E. (1977). Insecticides for the control of dieldrin-resistant banana weevil borer, *Cosmopolites sordidus* Germar. *Australian Journal of Experimental Agriculture and Animal Husbandry.* **17**: 499–504.

Zeck, E. H. and Eastwood, H. W. (1929). The banana aphid (*Pentalonia nigronervosa*, Coq.) *Agricultural Gazette of New South Wales* **40**: 675–80.

MISCELLANEOUS FRUIT AND NUT TREES

Fig pests

Commercial production of figs in New South Wales is carried out to only a limited extent, but the fruit is widely grown in farm and home gardens. The most suitable climatic areas for figs are in inland regions, such as the Murrumbidgee Irrigation Area, but some are also grown in Sydney's outer metropolitan districts. In inland districts, pest problems are neither common nor of much importance, and applied control is seldom needed in most seasons. A few pests do cause trouble in most fig-growing areas of the State, both coastal and inland – the most notable are the fig leaf beetle and fig bark beetle. Most other pests recorded as attacking figs have been either incidental or spasmodic in their appearance.

An account is given on pages 194 to 197 of the pests of figs listed below.

ARTHROPODA

INSECTA LEPIDOPTERA

Fig fruit borer	*Phycomorpha prasinochroa* (Meyrick)

DIPTERA

Queensland fruit fly	*Dacus tryoni* (Froggatt)

COLEOPTERA

Fig leaf beetle	*Poneridia semipullata* (Clark)
Fig longicorn	*Dihammus vastator* (Newman)
Fig bark beetle	*Aricerus eichoffi* (Blandford)
Large auger beetle	*Bostrychopsis jesuita* (Fabricius)

HEMIPTERA

Fig leafhopper	*Austroasca australica* Kirkaldy
Nigra scale	*Parasaissetia nigra* (Nietner)

ARACHNIDA ACARINA

Fig blister mite	*Eriophyes ficus* Cotte
Fig rust mite	*Rhyncaphytoptus ficifoliae* Keifer

The following insects are discussed as pests of other crops on the pages listed below, but may occasionally attack figs also.

INSECTA COLEOPTERA

Pumpkin beetle	*Aulacophora hilaris*	261
Dried fruit beetles	*Carpophilus* spp.	129
Monolepta beetle	*Monolepta australis*	43

INSECTA LEPIDOPTERA

Fig fruit borer *Phycomorpha prasinochroa*

Larvae of this native moth damage both wild and cultivated figs in coastal districts in late summer and autumn. They bore in to the green fruit to feed on the pulp, as well as in to shoot terminals and sometimes the midribs of leaves. The point of entry is visible as a mound of dark brown frass. The full-grown larva is about 12 millimetres long, cream-coloured and thick-set. The bell-shaped moth measures about 18 millimetres across the outspread wings, which are green with brown flecks.

Control measures If necessary, control might be achieved by spraying in mid-summer with azinphos-methyl 0.05 per cent or carbaryl 0.1 per cent.

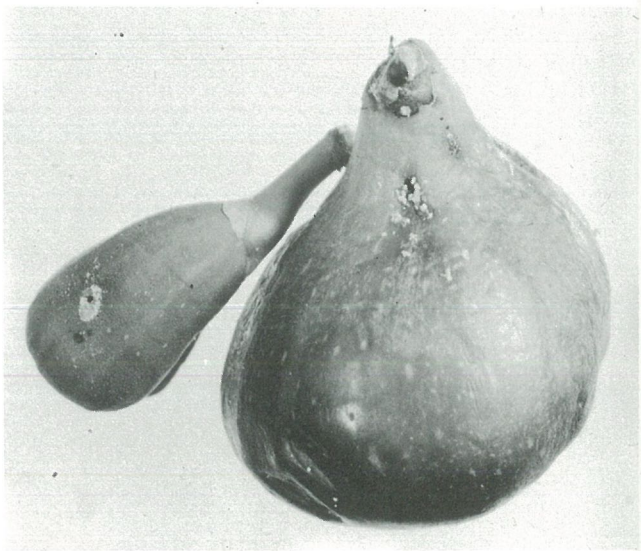


Fig fruit borer injury.

DIPTERA

Queensland fruit fly *Dacus tryoni*

Queensland fruit fly can cause considerable damage to ripening figs in some seasons. It is surprising that attractive crops of ripe figs sometimes remain free from fly in districts where the pest is established.

Figs are susceptible to injury by dimethoate, but other measures recommended for the control of fruit fly on page 129 under Peach and Nectarine Pests are suitable.

Fig leaf beetle *Poneridia semipullata*

Importance and Distribution These native beetles feed on wild figs, and when they infest cultivated figs they can do considerable damage. They are best known in coastal districts but do occur in inland areas, especially in the northern sections.

Conditions for Infestation Fig leaf beetle appears to be adapted to a summer-rainfall climate.

Plants attacked The beetle is only known to feed on members of the genus *Ficus.*

Description and Life History The adult beetle is about 10 millimetres long, and dull brown grading into reddish brown on the head and thorax. The pale yellow spindle-shaped eggs are laid on the leaves in clusters of about 50. The small larvae are yellow at first. They change to dark brown or black as they mature, and reach a length of about 12 millimetres. They are covered with tubercles, giving them a spiny appearance. They usually feed in groups and when full-fed, after about two weeks, they crawl down the trunk of the tree to pupate in the soil. After a further two weeks the adults emerge from the pupal cases, and crawl up the tree to feed and breed. There are several broods each year.

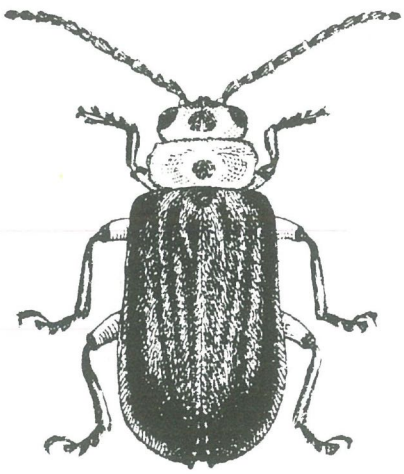


Fig leaf beetle. (Length about 11 mm)

Injury Both adults and larvae feed on leaves and fruit; the larvae do most damage by destroying many leaves. When the fruit is attacked the flesh is exposed but not eaten.

Dispersal The adults are strong fliers.

Control measures

NATURAL Of the various natural enemies of the fig leaf beetle, the predatory shield bug, *Cermatulus nasalis* (Westwood), is perhaps the most important. When there are many egg masses in a cultivated fig tree its foliage will usually be destroyed, or almost destroyed, if chemical control is not applied.

APPLIED Spraying with carbaryl 0.1 per cent should be effective.

Fig leaf beetle larvae, and damage.

Fig longicorn *Dihammus vastator*

In their natural habitats these beetles attack various wild species of *Ficus*, laying their eggs on trees that have been damaged by storms or that are showing decay for some other reason. They infest cultivated figs in coastal districts, and the larvae bore in to branches. They have also been known to attack citrus, grapevines, passionfruit vines, wisteria, and rock-lily.

The adult is a yellow-grey beetle about 3 centimetres long. The male has antennae about three times the length of the body. The sides of the thorax are extended into spines. The adults appear in spring, and the females lay eggs singly on rough bark, then gnaw a circular patch about 12 millimetres in diameter in the bark around each egg. The young larva eats its way into the wood, and grows to a length of about 4 centimetres. It is white and rather glossy, with very strong black jaws. It pupates just under the bark in a small cavity at the end of its tunnel. The pupa is white, about 2.5 centimetres long, rather flattened, and broadest across the middle. The larval tunnels may extend for a metre or more, and may go down into the roots; they may kill or seriously weaken important limbs.

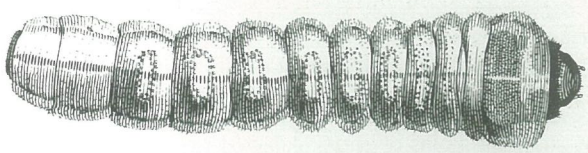


Fig longicorn larva. (Length, when fully developed, about 4 cm)

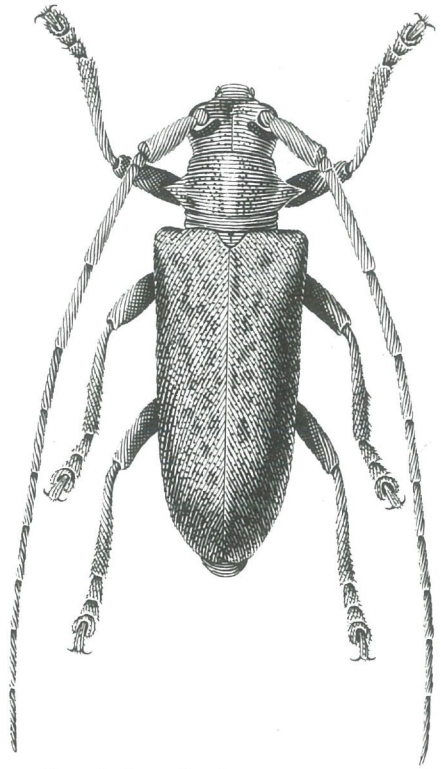


Fig longicorn. (Length about 3 cm)

Control measures Control of tree borers is difficult, so it is generally desirable to correct the loss of vigour which initially attracts the beetles. An attempt can be made to protect the trees from egg-laying by applying an insecticide with a long residual effect to kill or repel the adults when they move on to the tree. As the period of egg-laying activity may last from October to March, any such programme must begin in the spring and may involve two or three applications. A suggested treatment is DDT 1 per cent spray applied lightly to the trunk and framework of the tree up to about 1.5 metres from the ground. The fruit must not be in contact with the spray. If more than one application is made, the concentration may be halved.

Fig bark beetle *Aricerus eichoffi*

Fig bark beetle is a native found in coastal districts, where it commonly bores in to native *Ficus* spp. such as Moreton Bay fig. It is now common on domestic figs.

The adults are small, round, thick-set, reddish brown, and about 1 millimetre long. They tunnel out of twigs and their circular emergence holes are located near the axils of leaves. During the summer, the adults may be found on leaves and twigs nibbling the bark. The tiny larvae tunnel through the centres of terminal shoots. They are small white legless grubs and, when full-fed, they pupate inside the tunnels. Small piles of brown frass show the point of entry. Affected twigs usually die.

Control measures Control of this beetle is difficult, but repeated sprays of carbaryl 0.1 per cent during summer should kill the adults and thus prevent egg-laying.

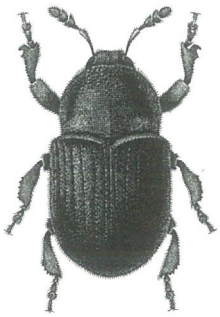


Fig bark beetle. (Length about 1 mm)

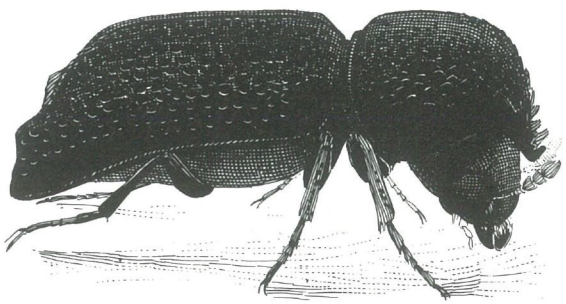
Large auger beetle *Bostrychopsis jesuita*

These destructive native beetles are common in inland districts. They damage many trees and shrubs, including eucalypts and wattles, as well as fig, apple, apricot, lemon and orange. They also attack fruit trees.

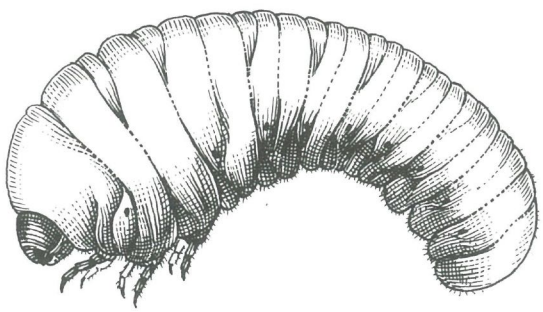
The adults vary in length from about 12 to 18 millimetres and are glossy black with reddish brown antennae. The head is characteristically turned down under the thorax of which the front part is spiny.

The female has been observed to lay her eggs just below the surface of the bark. The larva, a thick-set white grub with short legs, bores in the wood, filling the tunnel behind it with frass and undigested wood. Eventually it pupates at the end of the tunnel. Later the adult bores its way out through a circular exit tunnel. Adults begin to emerge in September, and they continue to do so through the spring months.

Control measures The control measure involving the use of DDT 1 per cent spray suggested above for the fig longicorn might also be effective against the large auger beetle.



Large auger beetle. (Length 12 to 18 mm)



Larva of large auger beetle.

HEMIPTERA

Fig leafhopper *Austroasca australica*

In coastal districts, the leaves of cultivated figs are commonly infested in summer and autumn by adults and nymphs of this insect. They can do considerable harm by sucking sap, mostly on the undersides of leaves, with young leaves being preferred. The leaves curl and become distorted; dying areas appear as brown patches, particularly along the main veins.

The adult leafhopper is torpedo-shaped and about 3 millimetres long. The body is yellow-orange with some dark brown or black areas on the dorsal surface, and the eyes are dark brown or black and rather prominent. Three ocelli (simple eyes) appear as dots between the compound eyes. The wings are mainly clear, with smoky bands on the front and rear margins of the forewings. The nymphs are wingless, fragile, and yellow with dark eyes. Both nymphs and adults are active. When disturbed they move sideways in a characteristic fashion.

Control measures Spraying with carbaryl 0.1 per cent usually wipes out the population, after which the tree produces new and normal-looking leaves.

Nigra scale *Parasaissetia nigra*

These smooth dark broadly-oval scales, up to 5 millimetres long, are often common on the leaves and twigs of figs, especially in the north-western inland areas. They usually congregate along the main veins of leaves. The young scales are light brown and soft. The mature females are dark, and have masses of eggs underneath their bodies. They produce copious honeydew which attracts ants and encourages the growth of sooty mould.

Control measures Control of this scale should be achieved by spraying with petroleum oil, or carbaryl plus petroleum oil, soon after the newly-hatched scales have settled on the leaves, as described on page 63 for black scale under Citrus Pests.

ARACHNIDA ACARINA

Fig blister mite *Eriophyes ficus*
Fig rust mite *Rhyncaphytoptus ficifoliae*

These two eriophyid mites are colourless or white worm-like mites which infest leaves, buds and twigs as well as fruit.

The blister mite is commonly found in green fruit and, occasionally, in ripe fruits. The mites occur in colonies and prefer the region near the opening or 'eye' of the fig. They cause rusty patches in the interior.

The rust or big-beaked mite has a flocculent coating of white, waxy material. The mites feed in large numbers on the upper surfaces of leaves, giving the leaves a rusty appearance, as well as on the bracts around the openings of the fruit receptacles.

Control measures Chemical control is not usually necessary, but wettable sulphur spray 0.2 per cent could be used if necessary. If the weather is hot, sulphur is very harmful to the tree.

Guava pests

Both the yellow guava and the cherry guava are grown to a limited extent in coastal New South Wales, mainly as household trees and ornamentals. Some people prize them for their fruit. The guava is attacked by few pests, the most important being the Queensland fruit fly. As they fruit late in the summer when the fly is most numerous and when other fruits are becoming scarce, the guavas attract a heavy infestation.

Control measures similar to those recommended on page 129 for peaches would be effective, but dimethoate is unsuitable as it is injurious to guava foliage.

Greenhouse thrips sometimes injure guavas when the trees are in protected situations. Some silvering and browning of the foliage, and sometimes blemishing of the fruit, may be seen in the late summer as a result of feeding by the thrips.

The larvae of the guava moth, *Coscinoptycha improbana* Meyrick, are commonly seen in the autumn, feeding on the flesh of the ripening fruit. The larvae resemble those of the yellow peach moth which may also attack guava fruits, in North Coast areas.

Olive pests

Commercial olive production is not of major importance in New South Wales, and is mainly in inland irrigation areas. Small blocks of olive trees are found near Sydney and individual trees are not uncommon in gardens and farm orchards.

In commercial orchards, scale insects are the main pests, particularly black scale and California red scale. The most destructive pest of olives in New South Wales is the olive lace bug.

INSECTA HEMIPTERA

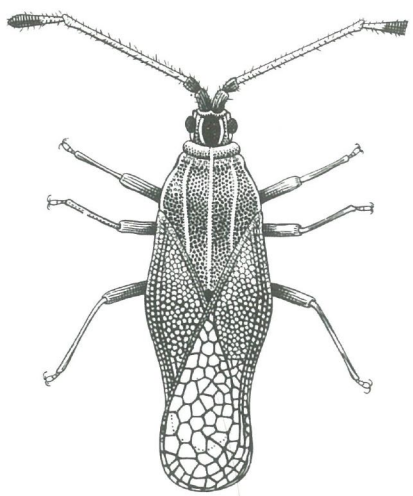
Olive lace bug *Froggattia olivinia* Froggatt

At the beginning of the twentieth century this native bug was recorded attacking cultivated olives, having turned its attention from its natural food plant, the native olive, *Notelaea longifolia*, to the cultivated species (Froggatt, 1901). It is found throughout the coastal districts and in the Murrumbidgee Irrigation Area, and can be extremely injurious to olive trees.

The bugs feed on the undersides of leaves and deposit their tarry excrement on the surface. The leaves become brown-grey and fall readily from the tree. Heavy attack may cause almost complete defoliation.

The bugs are about 3 millimetres long, mottled dark and light brown, with two pairs of stiff transparent wings that look as though they had been cut from fine gauze. The nymphs are covered with stiff spines. The eggs are laid on the leaf surface, each one being covered with a small cone of dark sticky excrement.

Control measures Control has been achieved by spraying thoroughly, to wet the undersurfaces of the leaves, with dimethoate 0.05 per cent or maldison 0.1 per cent.



Olive lace bug. (Length about 3 mm)

Black scale *Saissetia oleae* (Olivier)

Black scale has world-wide distribution. It attacks many other plants and is particularly well known on citrus.

The conspicuous dark brown scales are convex and bun-shaped. They are common on the leaves and twigs of olives, and produce a great deal of honeydew and thus a dense growth of sooty mould. The mould excludes light and reduces the vigour of the plant, causing leaves to yellow and fall and retarding fruit growth.

Details of the life history and control measures are given on page 61 under Citrus Pests.

Ross's black scale *Lindingaspis rossi* (Maskell)

This scale is sometimes seen on olives in inland and in coastal areas. The female's scale cover is black, flat and circular, about 2 millimetres in diameter and it sticks very tightly to the leaf surface. The male's scale cover is oval and smaller. The female's body, the eggs and the young larvae are purple, but the body of the male is orange.

Control measures are similar to those described for California red scale on page 49 under Citrus Pests.

Ross's black scale. (Diameter up to 2 mm)

California red scale *Aonidiella aurantii* (Maskell)

This is a very important pest of olives in the dry inland areas, or where trees grow in a dusty situation, such as in a fowl yard.

Leaf-fall and the die-back of twigs, and even branches, are the normal results of the infestation if it is left unchecked. California red scale on olive fruit reduces its size and gives it a pock-marked appearance, making it unfit for either pickling or oil production.

Details of life history and control measures are given on page 47 under Citrus Pests.

Olive parlatoria scale *Parlatoria oleae* (Colvée)

This is not a common pest. The adult female scale cover is dirty grey, broadly oval, about 1.5 millimetres long, and darker towards the head end. The males are elongate and much smaller than the females.

There appears to be only one generation per year. The scales infest leaves, twigs and fruit. If infestation is heavy, the fruit may be deformed. On ripening fruit, individual scales are often surrounded by a dark purple coloration that makes the infestation very conspicuous.

Control measures are similar to those recommended for California red scale on page 49 under Citrus Pests.

Note: Excessive use of oil sprays on olives should be avoided, as they can affect the appearance of the fruit and make it less suitable for processing. The oil can also harm the trees. It is suggested, therefore, that the insecticide plus petroleum oil 1 per cent combination sprays mentioned under Citrus Pests for scale control on citrus should be used for olives, instead of petroleum oil 2 per cent.

Persimmon pests

Persimmons are fairly common as garden fruit or ornamental trees in coastal districts, and are grown to a small extent in the Hills, Hawkesbury and North Coast districts of New South Wales. The only significant pests of persimmon are Queensland fruit fly, white wax scale, oleander scale and greenhouse thrips.

INSECTA DIPTERA

Queensland fruit fly *Dacus tryoni* (Froggatt)

The Queensland fruit fly will lay its eggs in all varieties of persimmons, but maggot development is rare. Fruit that have been 'stung' develop black blemishes which seriously down-grade them in appearance. As they ripen late in the season, persimmons may often be subjected to heavy attack by the many flies which have bred up on the other fruit available to them during summer. If persimmons are grown commercially, attention to fruit fly control will be necessary.

Control measures Control in commercial orchards should aim to reduce the fly population in order to eliminate 'stinging'. Materials like dimethoate and fenthion do not protect the fruit from 'stinging'. Bait-spray application with maldison-protein hydrolysate should begin well ahead of ripening, and should be repeated at least once per week and after rain.

THYSANOPTERA

Greenhouse thrips *Heliothrips haemorrhoidalis* (Bouché)

In some years, this black thrips may cause serious down-grading of persimmon fruit as a result of the lead-coloured speckled blemish produced where the thrips colonies feed – where fruits are in contact or a leaf presses against a fruit. Injury to leaves may also be important and result in significant leaf-fall.

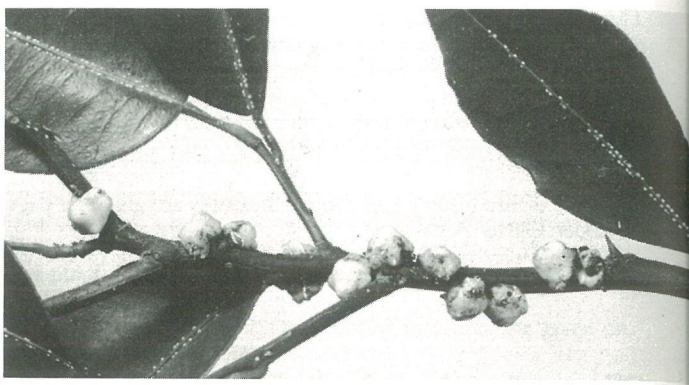
Control measures Watch should be kept from December onwards to anticipate a build-up of thrips on the fruit. If they become obvious, applications of maldison spray 0.05 per cent will give control.

Greenhouse thrips is described more fully on page 43 under Citrus Pests.

HEMIPTERA

White wax scale *Gascardia destructor* (Newstead)

This scale can infest persimmons heavily. Considerable blemishing of the ripe fruit may result from the associated sooty mould. Other injury seems to be only slight. Control can be achieved by applying petroleum oil spray when the young scales are out on the leaves in mid-summer, or a full strength soda-petroleum oil spray when the trees are bare in winter. See the discussion of white wax scale on page 56 under Citrus Pests.



White wax scale adults and larvae.

Oleander scale *Aspidiotus nerii* Bouché

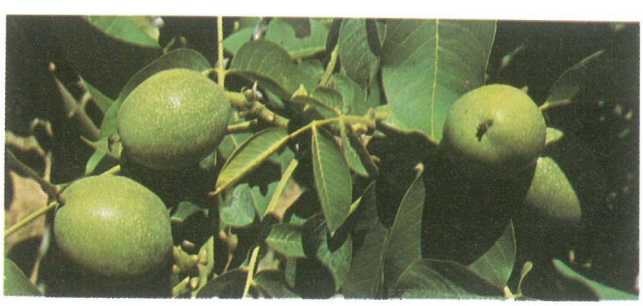
These scales may cause a down-grading of persimmon fruit because of blemishes. Infestation of the leaves and twigs is usually not important. The scales are mostly found on the upper surfaces of the fruit near the calyx. The female scale cover is circular, but sometimes irregular in shape, white to light brown, and 1 to 2 millimetres in diameter. The males are smaller and rather elongate.

Control measures similar to those recommended for California red scale on page 49 under Citrus Pests should be effective.

Walnut pests

Walnuts are grown only to a limited extent in New South Wales. The very few commercial plantings are in the cooler tableland areas. Pests recorded on walnuts include codling moth, Queensland fruit fly, two-spotted mite, and walnut blister mite.

Control measures, if necessary, for the first three pests would be similar to those discussed on pages 95, 100 and 114 respectively under Apple Pests.

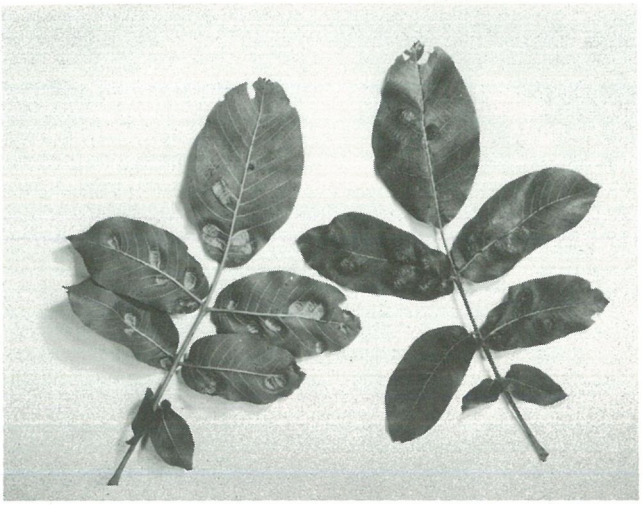


ARACHNIDA ACARINA

Walnut blister mite *Eriophyes tristriatus* (Nalepa)

These very small mites produce large blister-like swellings on the upper surface of a leaf. On the undersurface, the leaf becomes yellow or brown and felt-like in appearance. Large numbers of the white worm-like mites may be amongst the hairs. The pest is widely distributed in many countries including parts of Europe and North America, but was first seen in New South Wales at Batlow in 1937. A heavy infestation can cause some defoliation, but the pest is not important economically.

Control measures If control measures are considered to be necessary, lime-sulphur (polysulphides) 1.4 per cent spray applied in the late dormant period should be effective.



Upper and lower surfaces of walnut leaves showing walnut blister mite damage.

Reference

Froggatt, W. W. (1901). Notes on Australian Hemiptera (Plant Bugs). *Agricultural Gazette of New South Wales* **12**: 1592–601.

TRAILING BERRIES, BUSH FRUITS AND STRAWBERRY

Trailing berries and bush fruits pests

Trailing berries, such as loganberry, boysenberry and youngberry, and bush fruits, such as raspberry, gooseberry and black and red currants, are grown to only a very limited extent in New South Wales – on the tablelands and parts of the Southern Slopes. While these plants have important differences in their growth and fruiting characteristics, they do also have pests which are common to several of them. The few pests of importance will be considered together for this reason.

An account is given on pages 204 to 206 of the pests of trailing berries and bush fruits listed below.

ARTHROPODA

INSECTA		LEPIDOPTERA
Currant borer moth	*Synanthedon tipuliformis* (Clerck)	
		HYMENOPTERA
Bramble sawfly	*Philomastix macleaii* (Westwood)	
		THYSANOPTERA
Plague thrips	*Thrips imaginis* Bagnall	
		HEMIPTERA
Rose scale	*Aulacaspis rosae* Bouché	

The following have also been recorded attacking trailing berries and bush fruits, and are discussed as pests of other crops on the pages listed below.

INSECTA		LEPIDOPTERA
Light-brown apple moth	*Epiphyas postvittana*	96
		COLEOPTERA
Dried fruit beetles	*Carpophilus* spp.	129
		HEMIPTERA
Soft brown scale	*Coccus hesperidum*	64
Frosted scale	*Eulecanium pruinosum*	143
		ORTHOPTERA
Wingless grasshopper	*Phaulacridium vittatum*	111

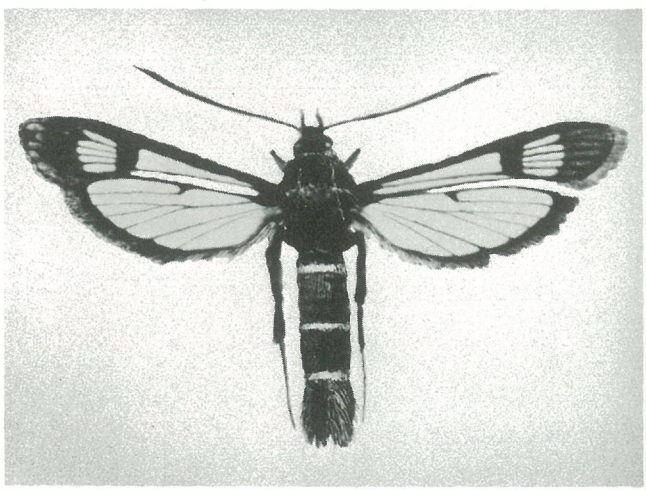
ARACHNIDA		ACARINA
Two-spotted mite	*Tetranychus urticae*	236

INSECTA — LEPIDOPTERA

Currant borer moth *Synanthedon tipuliformis*

This European moth was noted by Froggatt (1897) infesting black and red currants; it is now likely to appear wherever these currants are grown. It also attacks gooseberries and raspberries.

The adult is a small wasp-like moth about 2 centimetres across the outspread wings, black with yellow bands across the abdomen, and with clear wings. The tip of the abdomen has a fan-shaped mass of black hair-like scales. The light brown eggs are laid on new growth close to a bud or young shoot. The caterpillar hatches in ten to fourteen days and bores into the cane; it may go right down to the main root. It feeds throughout spring and summer, overwinters within the plant, and pupates in the next spring. The full-fed caterpillar has a yellowish body and dark brown head, and grows to a length of nearly 2 centimetres. The adults emerge from September onwards. Each female may lay 60 eggs. There is only one generation per year.



Currant borer moth. (Wingspan about 2 cm)

Currant borer moth caterpillar. (Length, when fully developed, about 2 cm)

Infested plants may be recognized in the spring by the dying-off of young shoots and the presence of yellowish undersized leaves. In the winter, small dead shoots and small mounds of frass around holes in the cane may be evident.

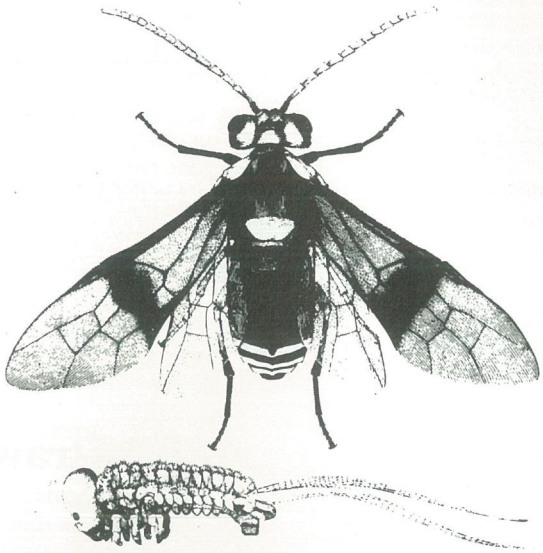
Control measures Pruning and burning infested canes will destroy many grubs and pupae, and this should be done before the moths emerge in October.

HYMENOPTERA

Bramble sawfly *Philomastix macleaii*

These grubs may almost defoliate loganberry and blackberry bushes. They have large heads and two long tail-like appendages. The adults are rather thick-set yellow-brown sawflies, 10 to 15 millimetres long, with smoky-yellow wings. There is a dark band across the centre of each forewing. They lay their eggs in slits in the leaf tissue.

Measures recommended for pear and cherry slug on page 149 under Cherry Pests should control them if necessary.



Bramble sawfly – adult above, larva below. (Length of adult 10 to 15 mm)

THYSANOPTERA

Plague thrips *Thrips imaginis*

Huge swarms of thrips infest the blossoms of boysenberries and raspberries in some springs, and prevent the development of drupelets. This results in fruit malformation.

Control measures Control is difficult, but if spraying is started when numbers of thrips are first seen on the flowers, and when fruit setting is just beginning, spraying with maldison 0.06 per cent will give a good level of protection. If the spraying is done in the evening when bees are not visiting the flowers, little harm will result.

Rose scale *Aulacaspis rosae*

This armoured scale sometimes infests the canes of trailing berries, and may cause weakness of the wood and even death of the canes. It is a very common pest of garden roses. Usually the older and more mature growth is attacked, but when the infestation is neglected, the younger canes also may be involved. The opaque white scale cover of the female insect is more or less circular, and measures 2 millimetres across. The smaller male scale cover is quite different as it is rectangular and has three distinct ridges in the white felted covering. The female produces tiny pale crimson eggs in clusters under the cover. The crawlers are pale red. They move out from beneath the cover and usually take up their feeding positions close to the parent. There are several generations in each year.

Control measures The web-forming caterpillar of the moth *Batrachedra* sp. often reduces populations rapidly.

Control is best carried out after pruning in the dormant period by spraying the plants thoroughly with superior dormant oil 3 per cent. It is important to ensure that the bases of the canes are wetted by the spray.

Rose scale.

Strawberry pests

Strawberry culture is carried out in many parts of New South Wales, but more in coastal districts than elsewhere. The main requirements are a warm (north-easterly) aspect, a suitably well-drained soil, and easy access to market. Strawberries are usually grown on black plastic sheeting (plastic mulch) which increases the difficulties in controlling soil insects. Pests and diseases continually threaten the crop, and they will severely limit production unless action is taken for their control.

Action is necessary to combat infestation prior to planting, and to reduce to a minimum the possibilities of invasion by pests from nearby sources. Many important strawberry pests are equally at home on other crops or on weeds. Amongst those that may be found in the strawberry bed or may invade from outside are cutworms, African black beetle, black field cricket, Rutherglen bug, wingless grasshopper, spider mites and slugs. The beds should be located as far away from weedy ground as possible. There should be a wide headland around the crop which should be kept free from heavy weed growth. The object of this is to keep some pests at a distance, and to minimize their introduction into the crop.

Early and thorough land preparation will help to reduce the attacks of pests on the strawberry crop. If the land has been under pasture, especially paspalum, there are likely to be white curl grubs or African black beetles in the soil which will turn their attention to the new crop. A long fallow will reduce the risk. Land that has been under lucerne or clover is likely to carry white fringed weevils. A winter cereal crop sown after the land has been ploughed for the first time will starve out the larvae. The early infestation of strawberry beds by soil insects has frequently been due to the neglect of these basic precautions. It is also essential that the runners planted in the well-prepared ground should be clean.

If adequate precautions are taken, the planting should remain free from attack by soil-inhabiting pests until the crop is well established.

Spraying strawberries.

An account is given on pages 207 to 212 of the pests of strawberry listed below.

ARTHROPODA
INSECTA LEPIDOPTERA

Loopers	*Chrysodeixis* spp.
Budworms	*Heliothis* spp.
Cutworms	*Agrotis* spp.
Cluster caterpillar	*Spodoptera litura* (Fabricius)
Light-brown apple moth	*Epiphyas postvittana* (Walker)
A leaf-roller caterpillar	*Cryptoptila immersana* (Walker)

COLEOPTERA

Strawberry weevil	*Rhinaria perdix* (Pascoe)
African black beetle	*Heteronychus arator* (Fabricius)
White fringed weevil	*Graphognathus leucoloma* (Boheman)
White curl grubs	Scarabaeidae
Fuller's rose weevil	*Asynonychus cervinus* (Boheman)
Spotted vegetable weevil	*Desiantha diversipes* (Pascoe)

THYSANOPTERA

Plague thrips	*Thrips imaginis* (Bagnall)

HEMIPTERA

Strawberry aphid	*Chaetosiphon fragaefolii* (Cockerell)
Green peach aphid	*Myzus persicae* (Sulzer)
Potato aphid	*Macrosiphum euphorbiae* (Thomas)
Rutherglen bug	*Nysius vinitor* Bergroth

ORTHOPTERA

Wingless grasshopper	*Phaulacridium vittatum* (Sjöstedt)
Black field cricket	*Teleogryllus commodus* (Walker)

ARACHNIDA ACARINA

Two-spotted mite	*Tetranychus urticae* Koch
Bean spider mite	*Tetranychus ludeni* Zacher
A flat mite	*Brevipalpus* sp.

MOLLUSCA
GASTROPODA SIGMURETHRA

Reticulated slug	*Deroceras reticulatum* (Müller)
Brown slug	*Deroceras caruanae* (Pollonera)
Black-keeled slug	*Milax gagates* (Draparnaud)

ARTHROPODA
INSECTA LEPIDOPTERA

Loopers *Chrysodeixis* spp.

These loopers are the larvae of thick-set brownish moths with small silver markings on their forewings. The moving caterpillar bends its body into a high arch and then extends its head end forward to attach its forefeet in a new position. The larvae feed on the undersurfaces of leaves, chewing irregularly-shaped holes, and they are difficult to see as their colour resembles that of their food. Their presence is usually indicated by the dark brown cylindrical pellets of excrement on the leaves below them. They pupate in folded leaves, or between leaves drawn together by a few threads.

Normally the loopers are important on strawberries only when the plants are growing in sheltered situations, and usually only in late summer.

Control measures On strawberries they can be controlled most effectively with methomyl 0.033 per cent spray or, in home gardens, with rotenone 0.5 per cent dust.

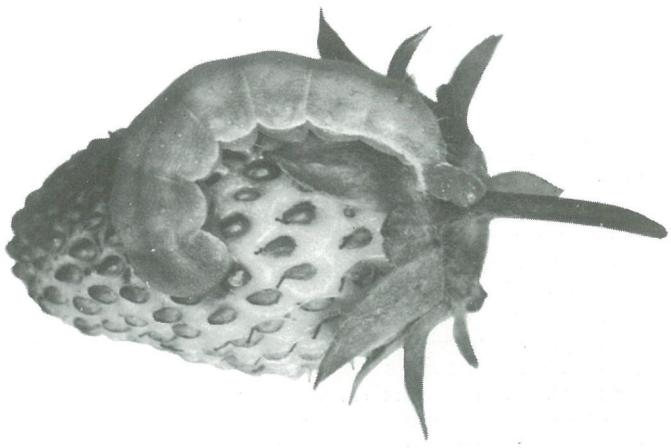
Further information is given on page 223 under Bean Pests.

Budworms *Heliothis* spp.

These caterpillars attack many crops and are commonly associated with strawberries, and may cause serious losses of fruit in bad years. They are pale green or creamy at first, but later become greenish, grey-green, yellow or buff with black or brown broad and narrow stripes. They damage young shoots and flowers, and bore into and chew young fruit.

Control measures Methomyl 0.33 per cent spray is an effective control measure on strawberries. Rotenone 0.5 per cent dust is suitable for use in home gardens.

Budworms are discussed more fully on page 219 under Bean Pests.



Budworm damaging strawberry.

Cutworms *Agrotis* spp.

Cutworms may be the larvae of any one of several species of noctuid moths. They are mostly brown, black, or pink-grey, and curl up in a circle when disturbed.

Strawberries may be attacked by cutworms particularly when the plants are set out in land recently under heavy weed growth. Cutworms are night-feeding caterpillars which hide at the base of the plant or in the soil during the day. They eat holes in leaves and ripening fruits and may chew across the stems of young plants.

Control measures Spraying affected plants and surrounding soil with endosulfan 0.07 per cent should be effective.

Cutworms and their control are described more fully on page 221 under Bean Pests.

Cluster caterpillar *Spodoptera litura*

During spring and summer, cluster caterpillar commonly infests strawberries, feeding on the foliage and the flowers. These caterpillars are 4 to 5 centimetres long when full-grown, and green to brownish purple with a row of dark triangular spots on each side of the body.

Control measures Spraying with methomyl 0.033 per cent or, in home gardens, using rotenone 0.5 per cent dust should be effective.

Further information is given on page 251 under Cruciferous Pests.

Cluster caterpillar damaging strawberry flowers. (Length of fully-developed caterpillar 4 to 5 cm)

Light-brown apple moth *Epiphyas postvittana*
A leaf-roller caterpillar *Cryptoptila immersana*

Leaf-roller caterpillars sometimes damage strawberries, particularly young foliage in autumn. They form webbing on leaves, flowers and fruits. Light-brown apple moth and *Cryptoptila immersana* have been recorded doing this damage.

Control measures Methomyl 0.033 per cent spray has been recommended for controlling these pests on strawberries.

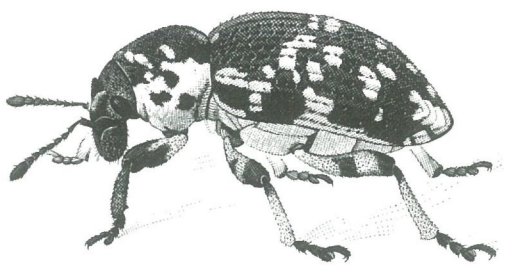
Light-brown apple moth is discussed on page 96 under Apple Pests.

COLEOPTERA

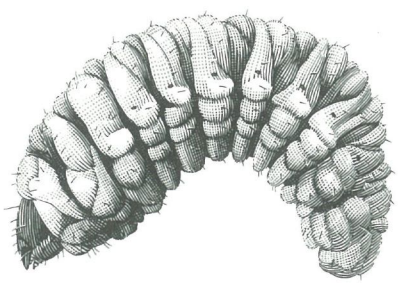
Strawberry weevil *Rhinaria perdix*

This species was recorded as a pest of strawberries in Victoria by French (1893). In New South Wales, an infestation near Bungendore was described by Froggatt (1915) who also gave details of the damage and life history. Very occasionally it has been reported to have done considerable damage, especially to crops in the Central Tablelands.

The adult is about 8 millimetres long, and has a short snout above which are two flattened horn-like processes between the black eyes. The base colour is dark brown, but the weevils are thickly covered with patches of minute cream and chocolate brown scales; this combination results in a variegated red-brown and white appearance. They are active and run about the foliage, but when disturbed they drop to the ground or hide under leaves. They fly readily.



Strawberry weevil. (Length about 8 mm)



Strawberry weevil larva.

Eggs are laid in the crown of the plant in late spring or early summer, and they hatch in about six weeks. The larvae bore in to the crown, feed on the woody tissue, and hollow out the centre of it. They may tunnel in to leaf stalks. When full-fed they pupate in the hollowed-out space or in the soil nearby. They overwinter as pupae, and the adults emerge in the spring. The weevils may appear as early as September, but emergence continues up to early November and they are most numerous in the strawberry beds in mid-summer. The damage leads to an invasion by fungi and the plants are often killed. A close watch should be kept for the first sign of adult weevils in the spring.

Control measures Methods of control have not been determined in New South Wales, but azinphos-methyl 0.05 per cent or carbaryl 0.1 per cent spray may be effective.

African black beetle *Heteronychus arator*

These shiny black oval beetles are about 12 millimetres long, and often attack ripening strawberries in the spring. They bore into fruits lying on the ground and hollow them out from underneath. Young plants may have the bases of stems and root crowns chewed in a ragged manner and tissues teased out, causing the plants to wilt rapidly and die. Damage is most likely when the beds are close to paspalum pasture in which the beetles have overwintered as adults. It may also happen when paspalum pasture land has been prepared inadequately for the planting of strawberries.

Losses of fruit can be reduced by scattering a lindane-broken maize bait lightly through the crop taking care not to contaminate fruiting plants. If the beetles are moving in from nearby pasture land, a deep steep-sided furrow can be ploughed around the outside of the crop area and the maize bait scattered in this. Young plants may be protected by jetting the soil around them with DDT 0.1 per cent.

African black beetle is described more fully on page 295 under Tomato Pests.

African black beetles in underside of a ripe strawberry. (Length of adults 12 mm)

White fringed weevil *Graphognathus leucoloma*

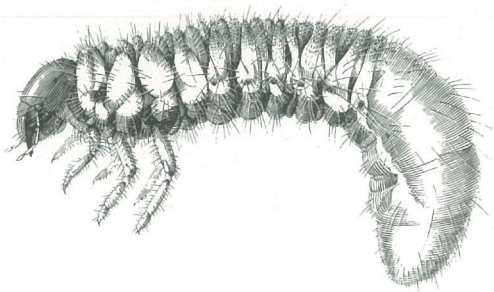
Strawberries planted out on land previously under lucerne or clover pasture may be attacked soon afterwards by the larvae of this weevil in the soil. They are thick-set white legless grubs with brown heads. Plants set out in autumn may show no damage until the spring, when the grubs attack as they become more active after the winter. Injured plants turn purple and growth stops. The roots will be found to be gouged and channelled, and larvae will sometimes be found in the root zone. Occasionally the adult weevils attack strawberry foliage.

Control measures Good control of the grubs of other weevil species, without harm to established plants, has been achieved overseas by the fumigation of the beds with ethylene dibromide (Eide, 1959).

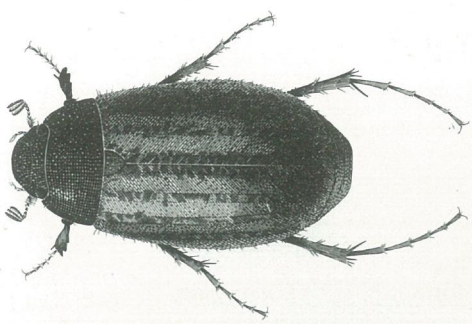
Further details of the life history and control of white fringed weevil are given on page 281 under Potato Pests.

White curl grubs Scarabaeidae

Larvae of several scarab beetles are known to attack strawberry plants, especially if these are set out in recently-ploughed grassland. The main species are Christmas beetles, *Anoplognathus* spp., pruinose scarab, *Sericesthis geminata* Boisduval, and dusky pasture scarab, *S. nigrolineata* (Boisduval). They feed on vegetable matter in the soil and, in their later stages, mainly on the roots of grasses. The plump smooth thick-set grubs are dirty white with brown heads and strong jaws. They curl up when disturbed. On strawberries, they eat off the roots right up to the crown. The plants stop growing and, if the weather is dry, soon wilt and die. The affected plants can easily be pulled from the ground.



Pruinose scarab larva. (Length about 19 mm)



Pruinose scarab. (Length about 16 mm)

Control measures Once an infestation is established, no effective control measures can be applied. Careful land preparation to avoid the trouble is the best insurance. Strawberry beds which have been heavily mulched with bush litter have been seen to suffer heavy attack from curl grubs, the eggs or larvae appear to have been introduced with the litter. Jetting with DDT 0.1 per cent has given some remission, but it is very difficult to achieve satisfactory control in beds mulched with plastic.

Fuller's rose weevil *Asynonychus cervinus*

Sometimes strawberry plants are attacked by this weevil in its adult stage, when it eats leaves along the edges to give a saw-toothed appearance. This happens during late summer and autumn. Spraying with carbaryl 0.1 per cent is suggested.

A more detailed account is given on page 36 under Citrus Pests.

Spotted vegetable weevil *Desiantha diversipes*

This native weevil has for a number of years attacked strawberry plants in the Bilpin district, in plantings producing runners for propagation. The adults feed on stems, leaves and runners in spring and summer. They lay eggs in late summer–autumn, from February onwards, and the larvae which hatch enter the soil, where they feed on the strawberry roots.

Control measures Adult weevils have been controlled by heavy applications of methidathion 0.05 per cent spray.

Spotted vegetable weevil is discussed also on page 255 under Cruciferous Pests.

THYSANOPTERA

Plague thrips *Thrips imaginis*

In some seasons huge numbers of these tiny brown insects swarm in the blossoms of many kinds of plants. The petals become brown and withered. In addition to feeding on the petals, the adult and yellow nymphal thrips feed on the stamens, pistil and ovaries. Seed-setting may be partly or wholly prevented. The fruit may be mis-shapen, with few seeds, and unfit for marketing as fresh fruit.

Control measures Control may be difficult due to continued re-infestation. Spraying with maldison 0.06 per cent is recommended. Extravagant use of insecticide on blossoms can be harmful to bees. Cropping should be watched in the spring, and the spray should be applied (in the evening to reduce the risk to bees) if thrips are numerous in the flowers.

Plague thrips are discussed in greater detail on page 102 under Apple Pests.

HEMIPTERA

Strawberry aphid *Chaetosiphon fragaefolii*
Green peach aphid *Myzus persicae*
Potato aphid *Macrosiphum euphorbiae*

These species of aphids may infest strawberries throughout the year, sometimes very heavily, with strawberry aphid being the most common. A heavy infestation of aphids on strawberries can do a great deal of damage, and may even lead to the death of plants. The associated honeydew can be very objectionable even if the crop is not obviously reduced. Damage may be more serious if it is accompanied by the transmission of virus diseases.

Control measures Many natural enemies attack the aphids. While they are generally too slow in breeding up to sufficient numbers to prevent damage by controlling the pests, it is desirable that insecticides harmful to the predators and parasites should not be used, or used only with discretion.

Spraying with the systemic insecticide dimethoate 0.03 per cent will control aphids.

Strawberry aphids.

Rutherglen bug *Nysius vinitor*

Strawberry beds may be invaded by swarms of immature and mature Rutherglen bugs in spring when their host weeds dry off. The plants are damaged, and fruits become malformed and may be tainted.

Control measures The crop can often be protected by running a steep-sided furrow between the weedy area and the crop, and pouring creosote along the bottom of the trench. When the bugs are already in the crop, spraying with maldison 0.06 per cent can kill those present and give some further protection. Mevinphos 0.05 per cent spray has been very effective, but special safety precautions must be observed for its use.

Further details on Rutherglen bug will be found on page 163 under Grape Pests.

ORTHOPTERA

Wingless grasshopper *Phaulacridium vittatum*

These small brown wingless grasshoppers sometimes invade and feed on strawberry plantings in the tablelands areas, moving in from pasture country nearby when dry summer weather forces them away from their natural hosts. Small shallow holes are chewed in ripening fruits.

Further description and control measures will be found on page 111 under Apple Pests and on page 275 under Pea Pests.

Black field cricket *Teleogryllus commodus*

In dry spring weather these crickets have caused serious damage by nibbling on green and ripening strawberries. They can be controlled with maldison-wheat bait, as described on page 258 under Cruciferous Pests.

ARACHNIDA ACARINA

Two-spotted mite *Tetranychus urticae*
Bean spider mite *Tetranychus ludeni*

These spider mites are the major pests of strawberries in coastal New South Wales during winter, spring and early summer, with two-spotted mite being numerically dominant. The spider mites have a very wide range of host plants, especially among low-growing herbaceous weeds, and frequently invade clean strawberry beds. The first sign of infestation is a speckling and mottling visible on the upper surfaces of the leaves. This is caused by the mites feeding on the undersides of the leaves, where silver and rusty markings can be seen, as well as the mites and their eggs, under fine white webbing.

Control measures Introduction of spider mites into strawberry plantings from infested weeds, for example on cultivation machinery or on clothing, should be avoided.

The predatory mites, *Amblyseius womersleyi* Schicha and *Phytoseiulus persimilis* Athias-Henriot, are generally present on plantings of strawberries. To ensure the most effective benefit from these natural enemies great care must be exercised in the thorough spraying of upper and lower surfaces of the leaves with cyhexatin 0.02 per cent or dicofol 0.04 per cent when this becomes necessary for spider mite control.

More details on these pests will be found on page 236 under Bean Pests.

Typical two-spotted mite adult females. (Length of adult about 0.5 mm)

Typical bean spider mite adult females, with young stage and an egg. (Length of adult about 0.5 mm)

A flat mite *Brevipalpus* sp.

These slow-moving dark red flat mites are occasionally seen on the undersides of leaves and on leaf stalks in dry weather in summer. They do not spin a web. Their eggs are bright red. The presence of these mites is indicated by speckling on the leaf, and dehydration if there are large numbers of mites. They do not usually seem to cause much harm. If it should be necessary, they may be dealt with by the methods recommended above for spider mites.

MOLLUSCA
GASTROPODA — SIGMURETHRA

Reticulated slug *Deroceras reticulatum*
Brown slug *Deroceras caruanae*
Black-keeled slug *Milax gagates*

Small black or grey slugs, up to 12 millimetres long, may do extensive damage to strawberries, especially in the home garden but also in commercial crops. Sometimes only tiny holes are made in the fruit but they induce mould development. Slugs graze the ripest part of a berry, so one slug may damage several berries on one plant in this way. They are favoured by prolonged periods of damp weather, and may multiply in the bed. They may also move to the bed from nearby weeds.

Control measures Bordeaux mixture spray (250 grams bluestone–250 grams lime–100 litres water) plus 1 per cent white oil is an effective repellent. Baits containing metaldehyde or methiocarb are effective in controlling slugs and snails, and are readily available in commercial preparations.

Slugs are discussed further on page 239 under Bean Pests.

References

Eide, P. M. (1959). Soil fumigation to control weevil grubs in strawberries. *Journal of Economic Entomology* **52**: 3–5.

French, C. (1893). *A Handbook of the Destructive Insects of Victoria. Part 2.* Government Printer, Melbourne. 222pp.

Froggatt, W. W. (1897). Entomological notes. *Agricultural Gazette of New South Wales* **8**: 99–104.

Froggatt, W. W. (1915). Insect pests of the strawberry. *Agricultural Gazette of New South Wales* **26**: 133–7.

VEGETABLES

Bean pests

Growing beans for marketing as green beans is an important industry in New South Wales. Dry beans are also grown, and beans for seed production are cultivated in some districts. These crops are all subject to a similar range of insect and mite pests, and routine control measures must be used for certain pests in some areas.

In coastal districts beans are grown mainly as fresh market crops. Inland, bean crops are mainly for the canning or quick-freeze trade, except in the New England region where fresh market crops are grown.

The time of sowing varies from one district to another. On the Far North Coast sowing usually begins in about April and may extend through until September, but the aim is generally to grow a winter crop. On the Mid-North Coast there are almost continuous sowings from late July to the end of March, while on the Far South Coast the major sowings take place in the November–December period. In the inland, sowings in the New England and Gundagai–Wagga areas are made in November–December; in the Forbes, Wellington, Dubbo and Narromine areas in late September–October and again in January–February; and in the Forbes–Canowindra area from November to January and, sometimes, in February.

The individual areas sown to beans may vary from about 0.25 hectare to more than 15 hectares. In the coastal districts the early crops are of particularly high value and pest control measures can be justified economically. Many of the inland crops are sown in broadacre plantings and, because of their lower value per hectare, may not justify much expenditure on pest control. The inland crops often escape serious pest infestation, so control treatments in these areas are the exception rather than the rule.

Although beans may be attacked by many different pests, not all of them are important. However, in some districts there must be routine treatments at certain times of the year if successful crops are to be grown. On the intensively-farmed coastal properties unnecessary trouble and chemical treatment can be avoided by adopting sound agronomic practices, as certain pests readily transfer from older spent bean crops to younger ones where crops are grown in succession. In inland areas the cultural practices differ, and a serious pest build-up is less likely.

An account is given on pages 219 to 239 of the pests of beans listed at right.

ARTHROPODA

INSECTA

LEPIDOPTERA

Budworms	*Heliothis armiger* (Hübner)
	Heliothis punctiger Wallengren
Cutworms	*Agrotis* spp.
Tobacco looper	*Chrysodeixis argentifera* Guenée
Green looper	*Chrysodeixis eriosoma* (Doubleday)
Bean pod borer	*Maruca testulalis* (Geyer)
Grass blue butterfly	*Zizina labradus* (Godart)

DIPTERA

Bean fly	*Ophiomyia phaseoli* (Tryon)
Seedling bean midge	*Smittia macleayi* (Skuse)
Onion maggot	*Delia platura* (Meigen)

COLEOPTERA

White fringed weevil	*Graphognathus leucoloma* (Boheman)
Fuller's rose weevil	*Asynonychus cervinus* (Boheman)
Leaf-eating ladybirds	*Henosepilachna* spp.
A green scarab beetle	*Diphucephala* sp.
Bean weevil	*Acanthoscelides obtectus* (Say)

THYSANOPTERA

Bean blossom thrips	*Taeniothrips nigricornis* Schmutz
Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

Green mirid	*Creontiades dilutus* (Stål)
Green vegetable bug	*Nezara viridula* (Linnaeus)
Rutherglen bug	*Nysius vinitor* Bergroth
Pod-sucking bug	*Riptortus serripes* (Fabricius)
Harlequin bug	*Dindymus versicolor* (Herrich-Schäffer)
Green stink bug	*Plautia affinis* Dallas
Passionvine hopper	*Scolypopa australis* (Walker)
Vegetable jassid	*Austroasca viridigrisea* (Paoli)
Cowpea aphid	*Aphis craccivora* Koch
Bean root aphid	*Smynthurodes betae* Westwood
Greenhouse whitefly	*Trialeurodes vaporariorum* (Westwood)

ARACHNIDA

ACARINA

Two-spotted mite	*Tetranychus urticae* Koch
Bean spider mite	*Tetranychus ludeni* Zacher
A flat mite	*Brevipalpus* sp.

CHILOPODA SCUTIGEROMORPHA

Garden symphylid

MOLLUSCA

GASTROPODA SIGMURETHRA

Common garden snail	*Helix aspersa* Müller
Reticulated slug	*Deroceras reticulatum* (Müller)
Brown slug	*Deroceras caruanae* (Pollonera)
Black-keeled slug	*Milax gagates* (Draparnaud)

ARTHROPODA

INSECTA LEPIDOPTERA

Budworms

Heliothis armiger
Heliothis punctiger

Importance and Distribution Members of this genus are amongst the most important pests of many subtropical crops wherever these crops are grown in the world. The two pest species in New South Wales are *Heliothis punctiger*, native budworm, and *H. armiger* which may be known as corn ear worm, tomato grub, tobacco budworm or cotton bollworm. Of the two, *H. armiger* is more common in coastal and subtropical areas, but *H. punctiger* is widely distributed throughout the State. Maize, sorghum, cotton, tobacco, linseed, lucerne, some deciduous fruits and many other crops and weeds may be attacked as well as vegetables. *H. punctiger* used to be confused with *H. armiger*, but in 1953 the distinctions were pointed out by Common.

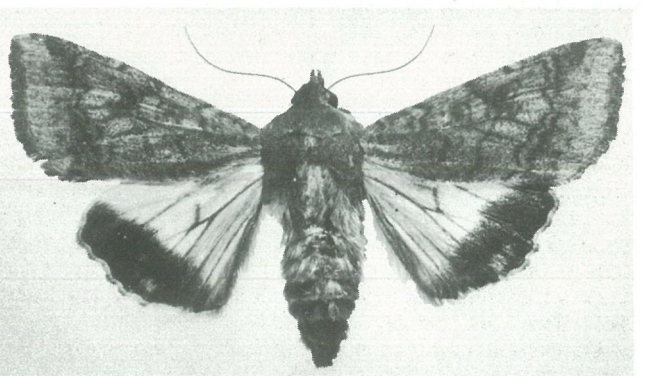
Conditions for Infestation Warm moist weather favours these insects. Emergence of adult moths from the pupal cases in the soil is stimulated by rainfall or irrigation, and delayed by long dry spells. Hot wet conditions sometimes induce the development of disease in the larvae which may sharply reduce numbers.

Plants attacked Budworms attack a wide variety of hosts, including weeds, garden plants and fruit trees, as well as the various crops after which they have been named. The larvae always seek to feed on fruits and seeds, although foliage may also be eaten. The plants most commonly attacked in the flower garden are perhaps calendula, snapdragon and hollyhock. The caterpillars will not infrequently leave herbage in which they have been breeding and ascend fruit trees to attack the young apples, peaches, plums and other fruit. Clovers, medics, and a wide range of weeds often support numbers of larvae.

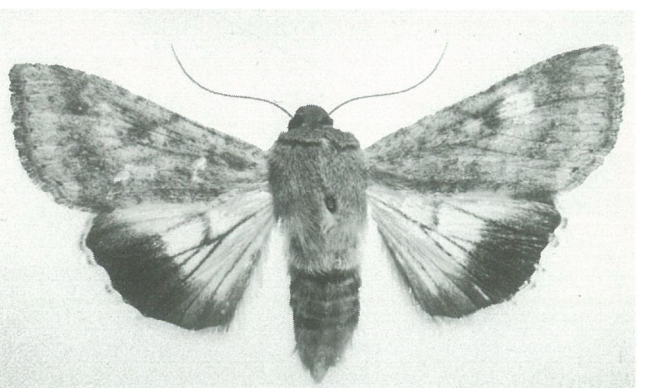
Description and Life History The adult moths are stout-bodied insects with a wingspan of about 4 centimetres. They vary in colour, but are generally buff to reddish brown with darker markings on the forewings and a black area at the outer margin of the pale hindwings. The dark markings on the forewings are more distinct in *H. armiger* than in *H. punctiger*, and there is a distinct light patch in the dark area of the outer margin of the hindwings in *H. armiger* which is rarely present, and then only in a very indistinct form, in *H. punctiger*.

The moths are inactive during the day and remain hidden amongst the foliage. They begin to fly at about dusk when they can be seen flitting amongst the plants, feeding on the nectar of flowers and laying eggs. They are usually to be seen about the tops of the plants, depositing eggs on the young growth. The eggs are cream-coloured or white, dome-shaped, about half the size of a pinhead and finely striated. They are laid on the tips of young growth, on the sepals and petals of flowers, and on newly-set young fruits. The adults live for about two weeks and each female may lay an average of about 1000 eggs.

The eggs hatch after about a week and the newly-hatched caterpillars may feed for a time on the young foliage or flowers. They soon move to buds, flowers or young fruit and eat their way in. A very young larva makes a small entry hole that is difficult to see, but larger grubs may move from one pod or fruit to another and thus produce fairly conspicuous entry holes. At first they are pale green or creamy in colour, but may change to various shades of green, yellow, buff or reddish brown, depending on the nature of the host plant; they have black or brown, broad and narrow, longitudinal stripes, often with a broad white stripe along each side of the body. The younger stages have



Heliothis punctiger. (Wingspan about 4 cm)



Heliothis armiger. (Wingspan about 4 cm)

conspicuous bristle-like hairs arising from dark tubercles on the body, but in the full-fed larva these are less prominent and the caterpillars may appear to be almost smooth. After two or three weeks in summer, or up to five weeks in cool weather, the caterpillars are full-grown – 4 to 5 centimetres long. At this stage they leave the plant, burrow into the soil to a depth of about 10 centimetres and pupate. The adults may emerge between two weeks and five months later, development being delayed by either cold weather or dryness of the soil. The shortest time for the complete life cycle from egg to adult is about 30 days; in spring and autumn the usual time is 40 to 50 days. Usually there are two main periods of infestation by *Heliothis* spp. – spring and early summer, and autumn.

Injury The main damage to beans by *Heliothis* spp. is to the pods, especially when the older larvae enter the pods and eat the seeds. Young larvae may also damage buds, flowers and young leaves.

Dispersal Although the moths usually make only short flights, up to about 50 metres, they are in fact strong fliers and may move over very long distances from their breeding source to a new host crop. They have an unerring instinct for finding

Budworms
Heliothis spp.

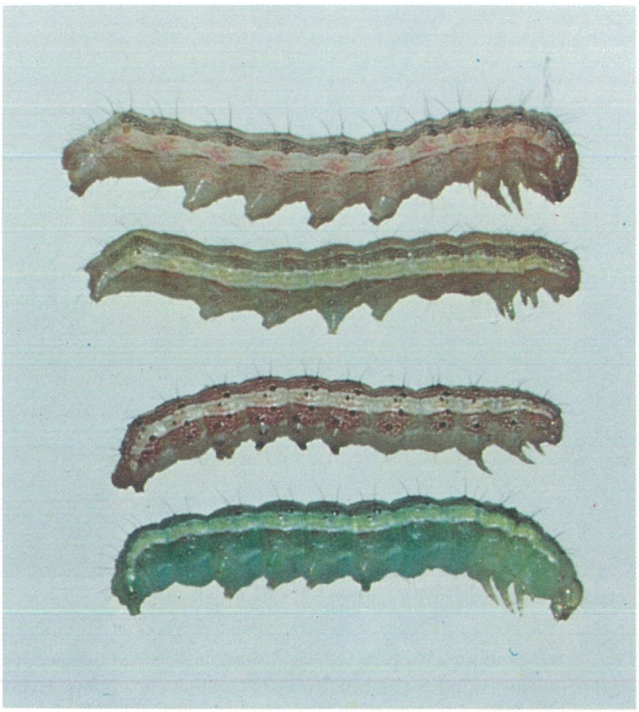
1 Eggs; enlarged thirteen times. **2** Larva or caterpillar; **3** pupa; **4** adult moth; all enlarged about 2.5 times. **5** Eggs on stem of flower bud; **6** young caterpillars attacking young fruit; **7** damaged tomatoes; **8** pupa in soil; all actual size.

a favoured host plant when it is in bloom. They are attracted in large numbers to lights.

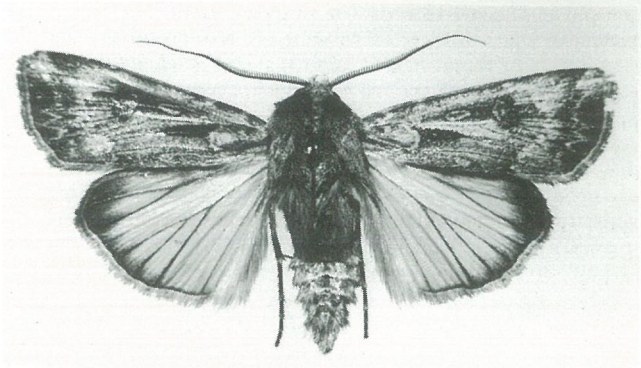
Control measures

NATURAL Many natural enemies, including parasitic and predacious insects, diseases and birds, play a part in reducing the *Heliothis* population. Natural control is rarely significant against infestations in vegetable crops.

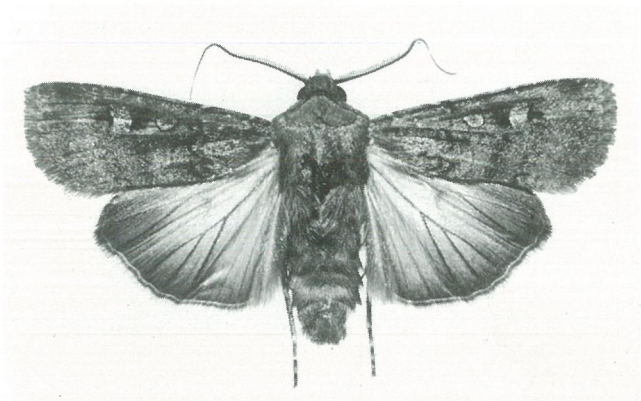
APPLIED Spraying with mevinphos 0.07 per cent will control the pest, but it must be used with great care because of its high toxicity. Methomyl 0.045 per cent is also effective.



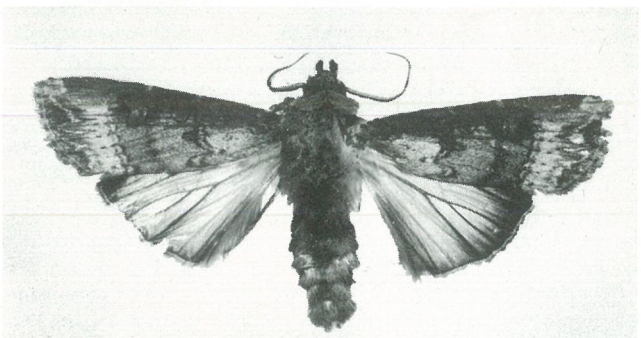
Budworm caterpillars – some colour variations. (Length of fully-developed caterpillar about 4 cm)



Brown or pink cutworm. (Wingspan up to 4 cm)



Bogong moth. (Wingspan up to 5 cm)



Black cutworm. (Wingspan up to 5.5 cm)

Cutworms *Agrotis* spp.

Importance and Distribution The larvae of several different species of noctuid moths, known collectively as 'cutworms', are night-feeding pests of vegetables. The name is derived from their habit of cutting off young plants, usually just above ground level.

Three species of *Agrotis* are commonly implicated – *A. munda* Walker, brown or pink cutworm, *A. infusa* (Boisduval), bogong moth, and *A. ipsilon* (Hufnagel), black cutworm. On the North Coast, the last is more common than the other two. The stout-bodied moths measure up to 5.5 centimetres across the outspread wings, and vary in colour from black to brown, grey or fawn, with markings on the forewings. The best known is probably the bogong moth. It has a row of three spots along the forewing which are lighter than the rusty brown to almost black background. The hindwing is lighter than the forewing.

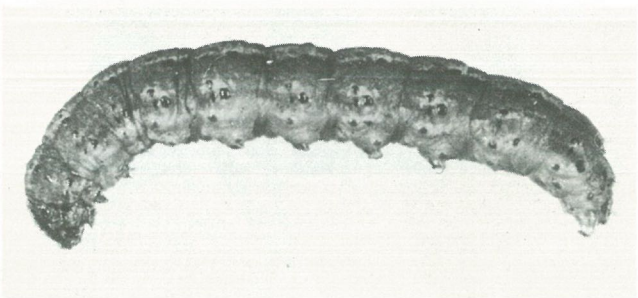
Conditions for Infestation Cutworms are likely to be present in soil that previously supported a heavy growth of weeds, especially on recently-flooded ground. It is not uncommon to find a heavy infestation in the low-lying parts of a field while the higher ground is free from the pest.

Plants attacked Weeds, vegetable crops, garden flowers and sometimes cereals are readily attacked. Recently-transplanted passionfruit vines and grape cuttings may also be attacked, but damage is most severe on young plants which have recently appeared above ground.

Description and Life History Each female moth may lay several hundred pearly white eggs which are round, about 1 millimetre in diameter, and usually grooved or sculptured. They

are laid in clusters close to the soil on the leaves and stems of plants, amongst litter, or on the soil surface beneath plants. The eggs hatch in three or four days in summer if conditions are moist, but they may remain viable for many weeks if they are dry. The young larvae are about 4 millimetres long and darkly coloured. They grow rapidly through a series of moults until they are about 4 centimetres long. The caterpillars are smooth, and may vary in colour from almost black through brown or green to dark pink. They are turgid and soft, and when disturbed coil up like watch springs and sham death. They hide in the soil by day and feed at night, and may often be found in numbers when clods are turned over. The first-stage larva may not do much damage because of its small size, but later stages feed ravenously for three or four weeks. The full-fed caterpillar then burrows about 5 centimetres down into the soil, before constructing an earthen cell in which to pupate.

The brown pupa is smooth and shining, about 18 millimetres long, and tapers sharply towards the tail end. In due course the adult moth emerges from the pupal case and makes its way to the surface. The time for pupal development depends on temperature and moisture, and may vary from fourteen days to many weeks.



Cutworm caterpillar. (Length, when fully developed, about 4 cm)

Young maize plant cut through at its base by cutworm.

Injury Young plants are the favourite food of these larvae, and may be girdled or cut through at the base so that they fall and die. Older plants may be heavily infested and suffer partial or complete defoliation.

Dispersal The adult moths have great powers of flight. On warm humid evenings large numbers may be seen hovering over crops and visiting plants in flower to feed on the nectar. The bogong moth has been known to take so much nectar from some eucalyptus species that it interferes with the yield of honey for beekeepers. They may shelter in the foliage of citrus trees in bloom and be an irritation to the pickers harvesting the fruit. They may travel for many miles, and swarms of cutworm moths have sometimes been reported far out to sea. The bogong moth is known to shelter in huge numbers in summer in mountainous country such as the Bogong High Plains.

Larval cutworms do not usually migrate. If numerous, they may denude a patch of ground before moving a short distance to another food source.

Control measures

NATURAL Many natural enemies attack cutworm caterpillars. Fly and wasp parasites, ground beetles and predacious bugs feed on them, as also do birds such as ibis, magpies, starlings and crows. In humid weather the cutworm population may be almost completely destroyed by disease. However, the influence of natural enemies on the cutworm population cannot be depended upon to save a crop of seedlings.

APPLIED Sowing a crop in well-fallowed land on which weeds have been controlled is the best defence against cutworms. Even so, in areas where an occasional weed has been missed and allowed to grow to a large size, cutworm moths are able to concentrate their egg-laying around such plants. Later these sites may be the source of heavy infestation when the crop appears above ground.

Weedy land that has been worked up a short time before sowing, and adjacent land that may be harbouring cutworms, should be treated with endosulfan 0.07 per cent spray before the crop is sown. Alternatively, a lindane-bran bait can be effective. This bait may be applied to the whole area before the crop is sown, or in the crop, or to known infested patches after the infestation is first seen. The bait should be spread in the early evening so that it is fresh and attractive when the cutworms emerge to seek food and when the birds have retired. It is used at the rate of 210 grams lindane and 26 kilograms bran, damped with 27 litres of water, per hectare.

If a growing crop is attacked, spraying the soil at the base of the plants with endosulfan 0.07 per cent spray is recommended.

Where cutworms are infesting a crop at the margins and seem to come from weedy ground, a strip of crop and weed about 10 metres wide should be sprayed or baited heavily.

Tobacco looper *Chrysodeixis argentifera*
Green looper *Chrysodeixis eriosoma*

Importance and Distribution These caterpillars are common pests of beans and many other crops, especially in the autumn. They attack beans in coastal districts in most years, but are rarely of importance on inland bean crops.

Conditions for Infestation Mild moist weather favours the loopers, and plants in shaded situations are more likely to be damaged than those elsewhere.

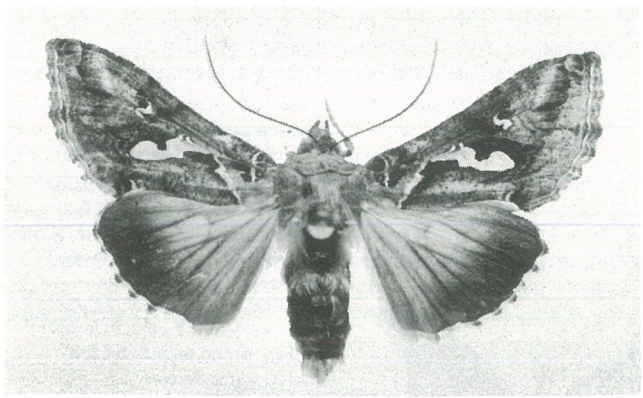
Plants attacked Most vegetable and garden plants, including pot plants, may be subject to attack, but beans and potatoes are the most commonly affected. Many broad-leafed weeds are often infested, as well as cotton and tobacco crops.

Description and Life History The adult moths are stoutly built, and measure 3 to 4 centimetres across the outspread wings. The forewings are coppery brown with lighter markings, and have two silvery spots towards the base of each wing. The hindwings are brown with a coppery sheen. The females lay their eggs on the foliage. The young caterpillars are slender, pale

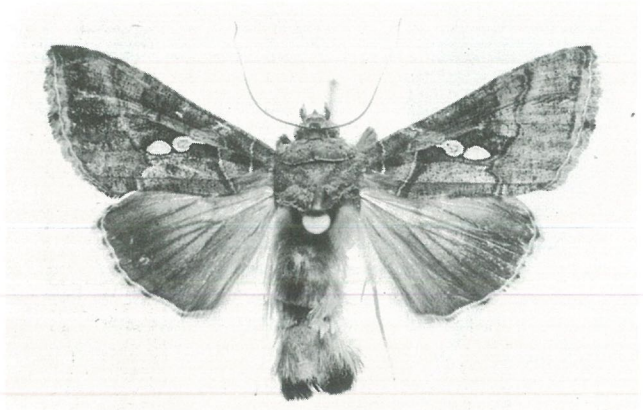
Green looper
Chrysodeixis eriosoma

1 Egg; enlarged fourteen times. **2** Larva or caterpillar; **3** pupa; **4** adult moth; all enlarged three times. **5** Bean foliage showing damage due to caterpillar feeding; **6** eggs on leaf; **7** fully fed caterpillar; **8** pupa in loose silken cocoon on leaf; **9** adult moth; all actual size.

green, translucent and very difficult to see as they feed on the undersides of young leaves. The older larvae are grass green, smooth and slender, and they move with a looping motion. When fully grown they are about 4 centimetres long. Nearly all feeding is on the undersides of leaves, but bean pods may also be attacked. When full-fed the caterpillar spins a silken cocoon attached to the underside of a leaf, and the brown pupa forms within this loose gauzy structure. The larva feeds for three or four weeks and the pupal stage lasts from ten to twenty days.

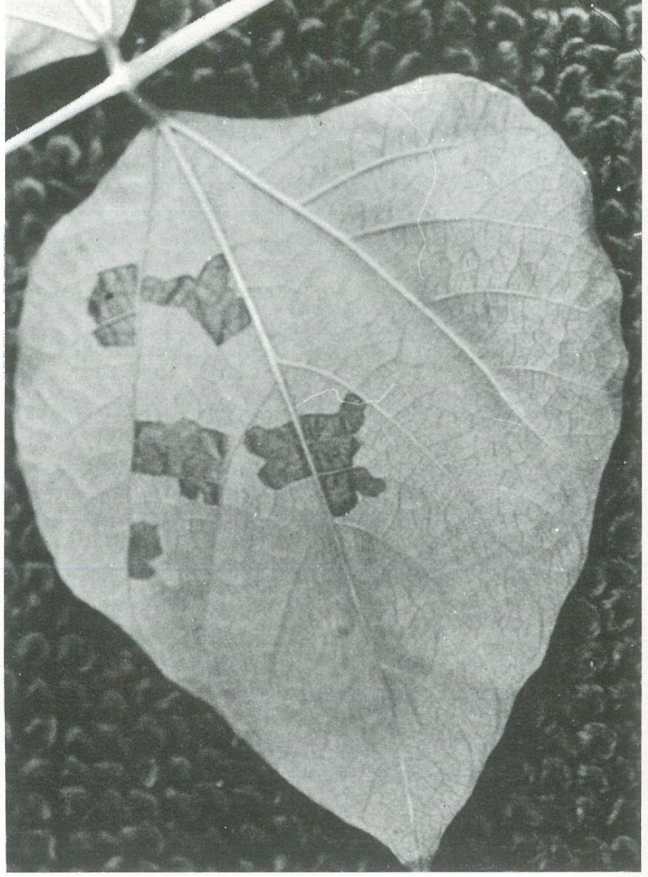


Tobacco looper. (Wingspan 3 to 4 cm)



Green looper. (Wingspan 3 to 4 cm)

A looper caterpillar. (Length, when fully developed, about 4 cm)



Bean leaf damaged by young looper caterpillars.

Injury The damage done by the early larval stages is confined to tender young foliage and consists of small holes eaten through, or partly through, the leaves. In the later stages, the larvae eat out large ragged holes in the leaves and excavate deeply into the maturing pods, sometimes almost cutting them in two.

Dispersal The moths are strong fliers, and may often be seen at dusk hovering over a bean crop. They are attracted to lights at night.

Control measures

NATURAL Looper infestations are often controlled by parasites, predators and disease before they cause much damage.

APPLIED Mevinphos 0.07 per cent will control heavy infestations, but, because of its high degree of toxicity, special precautions must be observed in handling it.

Bean pod borer *Maruca testulalis*

Importance and Distribution Severe infestations of the bean pod borer sometimes occur in late autumn in bean crops grown in the North Coast district. It is a common pest in Queensland, and has been recorded attacking various legumes in other tropical and subtropical countries.

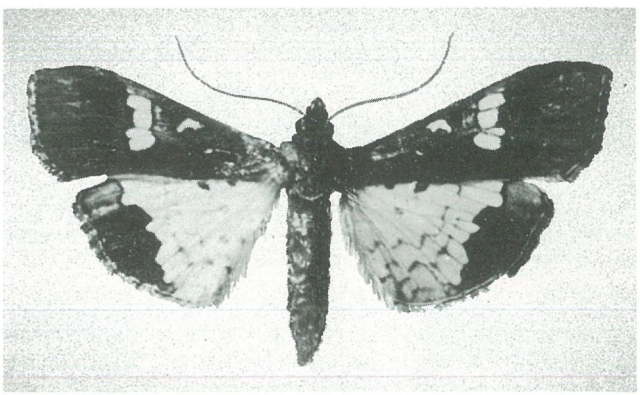
Conditions for Infestation In New South Wales, it is unlikely that this pest will cause trouble in any areas other than the relatively warm and moist North Coast.

Plants attacked Many legumes are attacked in Queensland, and considerable damage may be caused to the pods of French beans, long beans, sword beans, Tonga and jack beans (Anon, 1951).

Description and Life History The adult moth measures about 3 centimetres across the outspread wings, and has a smoky brown body and forewings, the latter having crescent-shaped black-edged white spots near their tips. The hindwings are light-coloured with brown bands at their tips, and are mostly free from scales except in the brownish fringe. The moths usually shelter in foliage during the day, and when disturbed fly rapidly to another sheltered spot nearby.

The eggs are laid on or near blossom buds, and the young larvae bore into the buds, blossoms or young pods; they feed mainly on the flowers and buds. Older larvae usually attack the pods, and their presence is indicated by the entrance hole through which a mass of excrement is extruded. When moving amongst the blossoms and pods, the larvae spin silken threads which cause the leaves, blossoms and pods to be meshed together by webbing.

Full-fed larvae are up to 2.5 centimetres long, and cream, light yellow or green with small dark spots on the body. They leave the plant to pupate in the soil.



Bean pod borer. (Wingspan about 3 cm)

Injury As well as attacking flowers and pods, the larvae of the bean pod borer will sometimes burrow down the leaf stalks of French beans.

Dispersal The adults are capable of rapid flight, and most of their movement takes place at night.

Control measures In Queensland, spraying with methomyl 0.025 per cent has been recommended.

Grass blue butterfly *Zizina labradus*

Importance and Distribution These small blue butterflies may be associated with legumes in most parts of New South Wales. They are only occasionally important as pests of beans, but may be active in spring, summer, and autumn; they are most likely to attack in summer. While the extent of the injury they cause is not great, the small holes that the larvae chew in developing pods detract from the appearance of the crop for market and may lead to breakdown and rotting.

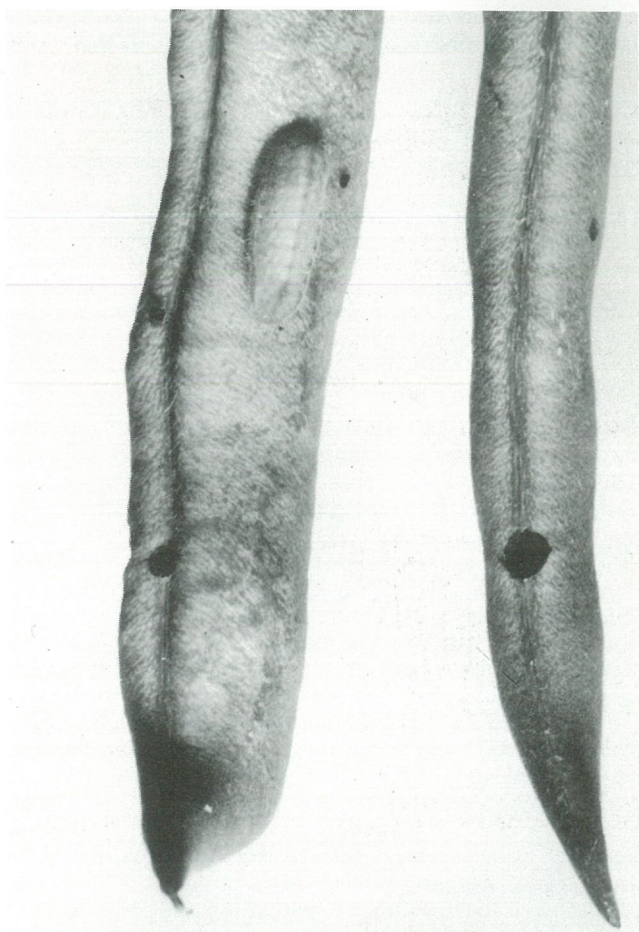
Conditions for Infestation These butterflies do not seem to be influenced significantly by weather conditions but they are generally most abundant when it is warm, dry and sunny.

Plants attacked The grass blue butterfly feeds on a wide variety of legumes, but is most commonly seen in association with lucerne. It is often called the clover blue or the lucerne blue butterfly.

Description and Life History The adult butterflies are slightly less than 2.5 centimetres across the outspread wings, which are dull blue with broad dull-brown margins in the female and bluish lilac with dull-brown outer margins in the male. The underside of the wing is greyish brown with faint white markings.

The flattened, somewhat spherical, white or bluish eggs are deposited on the tender young foliage and amongst the buds and blossoms. The full-grown larvae are 10 millimetres long, and pale green with minute white dots and a pale white line at each side. They are rather slug-like and slightly hairy. They transform into pinkish, greyish or greenish cream pupae with darker lines along the back. The pupae attach themselves to the plant by a silken girdle.

Injury The larvae chew small holes in the youngest leaves and feed on the buds and flowers. The most important damage is to the young pods, especially when they are 5 to 8 centimetres long; the larvae chew small round holes in the outer pod walls.



Grass blue butterfly larva and damaged beans.

Dispersal The adults are strong fliers.

Control measures If control measures become necessary, spraying with mevinphos 0.07 per cent should be effective. Special care is required in handling mevinphos because of its high toxicity.

DIPTERA

Bean fly *Ophiomyia phaseoli*

Importance and Distribution This pest appears regularly on summer and autumn bean crops in the coastal districts of New South Wales, and may destroy the crop if not controlled. Infestation can be expected from Gosford northwards during and after December and, in some years, it may be important later in the season on the South Coast. Infestation is sometimes seen in crops in the north-western inland as far west as Moree. Bean fly is a serious pest in Africa, the Middle East, India and the Pacific Islands. It was first recorded in New South Wales in 1898 (Froggatt, 1899).

Conditions for Infestation Damage by bean fly in summer and autumn may be expected in districts which have humid summer weather, and where a succession of bean crops in the spring allows a population build-up. In New South Wales numbers are always greatly reduced by a high winter mortality of pupae, and do not increase fast enough in spring to cause appreciable damage before December.

Plants attacked French beans are the most susceptible plants, but other types of beans are sometimes infested. Development does not take place on broad beans though eggs may be laid in the leaves.

Description and Life History The glossy black adult flies are robust and about 2 millimetres long. They are easily seen while egg-laying on the upper surface of leaves. The eggs are placed in slit-like punctures in the tissue, usually at the base of the leaf blade. The tissue around each puncture turns yellow. The tiny larvae mine for a short time in the leaf before tunnelling down through the leaf stalk into the stem. They make fine tracings in the leaf tissue, but the tunnels are seen as wider light-coloured markings down the side of the stem just under the surface. The full-fed larvae pupate in the outer tissue of the stems. In warm weather the eggs hatch after about three days; the larvae feed for eight or nine days, and the adults emerge from the pupae after nine or ten days. In summer, the minimum period from egg-laying to adult is less than three weeks. In colder weather, development may be much slower and could extend over as many as twelve days for incubation, up to seven weeks for the larval stage and four weeks in the pupal stage. A single female may lay up to 300 eggs at a rate of 30 to 40 eggs per day. Flies have been kept alive in cages for as long as six weeks, but in nature few probably live for longer than three or four weeks.

Injury Maggots hatched from eggs laid in the first pair of leaves will be feeding in the stem at ground level before the plants have been above ground for more than one week. If the infestation is severe, these young plants will turn yellow and die, or may wilt and be pushed over readily by wind. Eight to ten maggots can kill a seedling, though more may be present. If the plant survives and growth continues, the stem becomes blistered with longitudinal cracks and such plants will produce a poor crop of inferior beans.

When older plants are attacked, maggots tunnel down from higher leaves; branches and branchlets are weakened and will break off readily in the wind or during picking. While the yield of late-infested plants may not be much reduced, the pods are likely to be tough and flabby.

Young bean plant severely damaged by bean fly.

Dispersal Bean flies, though small, are vigorous insects and capable of brisk flight. Beans sown in isolated situations have been found to be heavily infested in the autumn, suggesting that the flies have migrated over considerable distances. If a succession of crops is grown in one locality, those maturing in the autumn are almost certain to be heavily infested unless careful control measures have been taken.

Control measures

NATURAL Bean fly pupae are heavily parasitized by numerous wasp parasites (Kleinschmidt, 1970) particularly late in the season, and this contributes to the reduction of the fly population in the winter. Control is also promoted by predacious ground beetles, as well as by the effects of low temperatures on the pupae during the long pupal period at this time of year.

APPLIED Until the mid-1930s commercial bean production was made almost impossible due to bean fly attack on the Central Coast of New South Wales if plantings were made before mid-March. This late planting had to be associated with good husbandry, including hilling of the crop.

Research showed that the fly maggots could be killed in the leaves and stalks by sprays of nicotine sulphate plus white oil (Morgan, 1938a, 1938b), but successful control required spraying at intervals of three or four days. The introduction of DDT permitted the intervals to be extended to seven days (Hely, 1948, 1955), but DDT stimulated the increase of spider mite populations and its use is no longer recommended.

Several of the newer insecticides have been found to be effective, and dimethoate 0.03 per cent spray is recommended. The

Bean fly
Ophiomyia phaseoli

1 Egg in puncture in leaf; **2** adult; **3** bean stem cut open to show larva in tunnel; **4** pupa; all enlarged forty times. **5** Bean plants showing flies and egg punctures on upper leaf surface, and damage to stems by larvae; actual size.

recommended routine is to spray when the earliest plants have been above ground for three days, and then spray again three days later (to allow for uneven germination), and then at weekly intervals until blossoming. This involves about six treatments for beans planted in January, while the first three treatments may be sufficient for later-sown crops. The spray needs to contact only the upper surfaces of the leaves, and it can be applied most easily in the early morning when the bean leaves are held flat, and not erect as they are in the hotter part of the day. Diazinon 0.025 per cent may be used instead of dimethoate.

Damage from the earliest attack on young seedlings has been prevented by treating the seed with endrin. This allowed the start of spraying to be delayed until the plants were above ground for three weeks. The seeds were treated with endrin 20 per cent emulsifiable concentrate by shaking them gently in a large container until thoroughly wetted. A kilogram of seed was treated with 10 millilitres of 20 per cent concentrate. After treatment seed was spread on paper to dry in the shade, and was sown within a few days. Only seed with good germination capacity was suitable (Gellatley, 1966).

Seedling bean midge *Smittia macleayi*

Importance and Distribution Early beans in coastal districts are sometimes damaged by the larvae of this pest, when seeds are slow to germinate due to cold weather in spring. Usually only an odd plant here and there is seriously affected, but sometimes gaps are left in the rows and, in extreme cases, the area may need to be re-planted.

Conditions for Infestation Planting in unsuitable positions is the main reason for an attack by this insect. Beans planted on high well-drained slopes seldom suffer any damage. Early crops, particularly, should not be sown in wet situations. Infestation in early spring is likely on beans sown in land which has recently been dressed with large quantities of fresh poultry or farmyard manure, or into which heavy growths of greenstuff have recently been ploughed.

Plants attacked As well as beans, early crops of cucumbers and squashes have also been seen to be infested.

Description and Life History Seedling bean midge was first reported in New South Wales by McCarthy (1922). The damage is done by the maggots which develop into these small black midges. They are often seen in the evening dancing in the air in swarms, not far above the soil. The male is about 2.5 millimetres long, slightly longer than the female and has bushy antennae. The tiny eggs are laid amongst organic matter on the soil and hatch into delicate white thread-like maggots that grow to a length of about 5 millimetres. Normally the maggots feed on decaying organic matter, but they are attracted to slowly-germinating bean seeds and enter the seed as soon as the coat bursts. They feed on the cotyledons (seed leaves) and primary leaves. When full-fed, the maggots pupate in the soil.

Seedling bean midge – adult male. (Length about 2.5 mm)

Injury The maggots tear at the tissues of the primary leaves and cotyledons. Decay often follows, and the seedling is destroyed before it reaches above ground level. In many cases the stem appears with only the seed leaves and such plants are referred to as 'blind stems'. When the injury is less severe, the expanding primary leaves are fretted and lacy and the plants are slow to develop.

Dispersal The adults are capable of flight over short distances. As they are not dependent on growing plants for food, they are likely to occur in any situation where organic matter is abundant and the moisture level is satisfactory.

Control measures As the larvae are delicate and die quickly when exposed, cultivation destroys large numbers. Trouble need not be expected when beans are sown in land where germination is normally rapid; this effect may be reinforced by shallow planting, where moisture conditions allow it.

Onion maggot *Delia platura*

Importance and Distribution Bean crops in the Sydney and Gosford districts are sometimes injured by the larvae of this small fly, as it thins out the plantings causing gaps in the rows.

Conditions for Infestation Attack is most likely to occur in spring after a wet winter, and beans on sandy soils are the most susceptible. Applying blood and bone fertilizer or other organic manures shortly before planting also encourages onion maggot attack.

Plants attacked In New South Wales, onion maggot is a pest of onion, bean, crucifers and cucurbits.

Description and Life History The adult flies are greyish brown, slightly hairy and about 5 millimetres long. They are commonly seen flying about over the soil, especially after it has been topdressed with blood and bone fertilizer. Eggs are laid on the soil. The maggots are thought to feed mainly on organic matter. When they encounter the stem of a germinating bean plant they tear at it with their strong hooked jaws, then enter the stem and eat it out, thus destroying the plant. Maggots which do not become fully fed by entering a single stem will attack other stems nearby, often only partly injuring them, but as many as twenty maggots may commonly be found attacking one bean plant. The full-grown maggots are yellowish white, legless, tough-skinned and about 6 millimetres long. They pupate in the soil near the infested plant; the pupae are barrel-shaped, brown and about 5 millimetres long. The larval stage lasts for about twenty days and the pupal stage for about fifteen days in summer.

Injury The maggots bore into the stems and hollow them out below ground. This causes young plants at the two-leaf stage to wilt suddenly and topple over. Generally only a few plants in any one spot are affected.

Dispersal The adults can fly strongly.

Control measures In susceptible areas, the spring and autumn crops should not be fertilized with manures containing blood and bone or heavily dressed with animal manures. Experiments have shown that plantings treated in this way are attacked, while others receiving inorganic fertilizers have not been infested.

Seed treatments against the onion maggot have been used successfully overseas, but their use has not been considered necessary for beans in Australia.

White fringed weevil *Graphognathus leucoloma*

Beans sown in land which has been under lucerne or pasture with a clover content, or which has been under a heavy growth of susceptible broad-leafed weeds, are sometimes attacked by the larvae of the white fringed weevil. This insect is widely distributed throughout New South Wales and is most likely to

be present in river-flat country, although it is not restricted to such areas.

White fringed weevil is discussed more fully on page 281 under Potato Pests.

Fuller's rose weevil *Asynonychus cervinus*

Beans are sometimes injured by both the adult weevils and the larvae. The adults attack in late summer and autumn; they chew pieces from the edges of the leaves, producing a saw-toothed appearance. This type of infestation usually results from a spill-over of the populations on nearby weeds. If the damage is considered to be important, the weevil can be controlled by spraying with carbaryl 0.1 per cent.

More serious damage is sometimes done to beans by the larvae. Early crops are the ones which are attacked in the spring, as may also happen to tomato and cucurbit crops. The larvae destroy the fibrous root system and gouge out the main root. This may kill the bean plant or reduce the quantity and quality of the crop. This type of damage is likely to occur where spring beans are sown on land that was weedy during the previous autumn. The attack may be made by grubs that were feeding on the weeds when the ground was cultivated, or by younger grubs which hatched in the spring from eggs overwintering on the weeds. No control measures are effective once the plants have been attacked, but the damage should be prevented as far as possible by thorough early preparation of the land. Preparation by ploughing in the weeds in late summer and growing a crop of oats to be grazed or ploughed in is recommended.

This insect is discussed more fully on page 36 under Citrus Pests.

Leaf-eating ladybirds *Henosepilachna* spp.

The adult ladybirds and their spiny larvae sometimes appear on beans after they have been numerous on neighbouring crops and weeds. By grazing only on the leaf surfaces they usually leave one surface uneaten, giving the foliage a brown lace-like appearance.

Control measures Carbaryl spray 0.1 per cent, used sparingly to ensure that spider mite activity is not stimulated, is the recommended control measure. The spray should come into contact with both surfaces of the leaves.

These beetles are described in greater detail on page 262 under Cucurbit Pests.

A green scarab beetle *Diphucephala* sp.

These bright green scarab beetles are about 8 millimetres long, and have a metallic sheen on their wings. In the Hawkesbury River districts they sometimes cluster in large numbers on bean plants. They may chew foliage heavily, and can strip the plants down to a ragged skeleton in a short time. Only the adult beetles attack beans. The larvae are curl grubs in the soil, but details of their breeding are not known. The attack occurs in summer and is short-lived.

When the beetles appear, they can be controlled by methods similar to those recommended above for leaf-eating ladybirds.

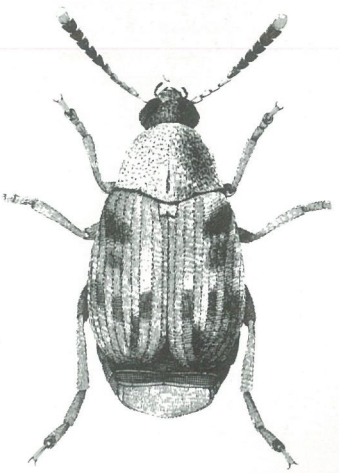
Bean weevil *Acanthoscelides obtectus*

Importance and Distribution Although this insect is called a weevil, it does not belong to the weevil family. It is a widespread and destructive pest of bean seeds. Infestation may take place in the field, or in storage where it may go unnoticed until the time for planting when the seed is found to be heavily damaged.

Conditions for Infestation Warm dry conditions suit the beetles best when attacking beans in the field, but in storage they may breed throughout the year.

Plants attacked All beans and cowpeas may be infested in the field. Peas may be damaged in storage also.

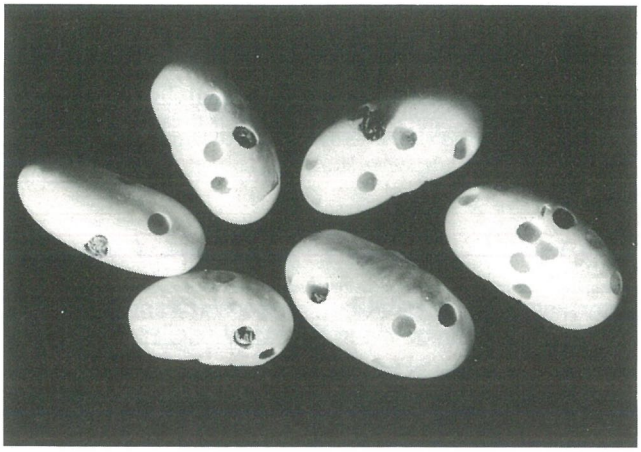
Description and Life History The adults are stout brown beetles, about 3 millimetres long, with white, grey, brown or black patches on the upper surface. The legs and antennae are reddish. The females lay their eggs in loose groups on bean pods in the field, selecting mature and drying pods. The first-stage larvae have legs; they move through the pods and bore into seeds. Later-stage larvae are legless; they grow to a length of 3 millimetres inside the beans and then pupate. The adults eat their way out, leaving circular holes, and then infest other seeds in the store. There are several generations in a year. Infested seed that has not been treated may be found to be riddled when it is needed for planting.



Bean weevil. (Length about 3 mm)

Injury Infested seed should not be planted because it may contain many seeds which are ruined by damage that is not obvious from outside, or it may be so weakened that germination will be irregular and some plants stunted.

Dispersal The adults fly strongly and can invade the bean field from places where seed was stored. All stages are difficult to detect in lightly infested seed.



Bean seed infested by bean weevil.

Control measures When beans are harvested for seed, they should be bagged as soon as they are dry and fumigated in an air-tight container using carbon bisulphide 60 millilitres per cubic metre for 24 hours above 20°C. The carbon bisulphide may be poured on to the bagging or into a shallow vessel placed on top of the seed. The container should be opened after 24 hours, as a longer exposure might kill some of the seed. **It must be remembered that carbon bisulphide gas, as well as being poisonous, forms an explosive mixture with air.** Every precaution must be taken to keep lights and heated objects away from the operation. Methyl bromide fumigation is suitable for large quantities of seed.

As an alternative to fumigation, seed thought to be clean or known to be lightly infested may be dusted with either lindane 0.5 per cent at 60 grams per 30 kilograms or magnesite at 0.5 kilograms per 30 kilograms. Although the dusts do not affect the larvae or pupae inside the seed, they do kill the adults as they emerge. Copper oxychloride dust, at the same rate as magnesite, will also give good protection. After treatment, bean seed stored in beetle-proof sacks or muslin bags will remain free from infestation for a long time.

THYSANOPTERA

Bean blossom thrips *Taeniothrips nigricornis*

Importance and Distribution Bean blossom thrips infest bean crop blossoms in coastal districts in the autumn, resulting in distorted pods. The trouble is usually not seen until autumn, but it may occasionally be significant as early as January when a succession of plantings has allowed the population to build up.

Conditions for Infestation Warm weather and some humidity are necessary to this pest, so it has not been seen on beans in inland districts.

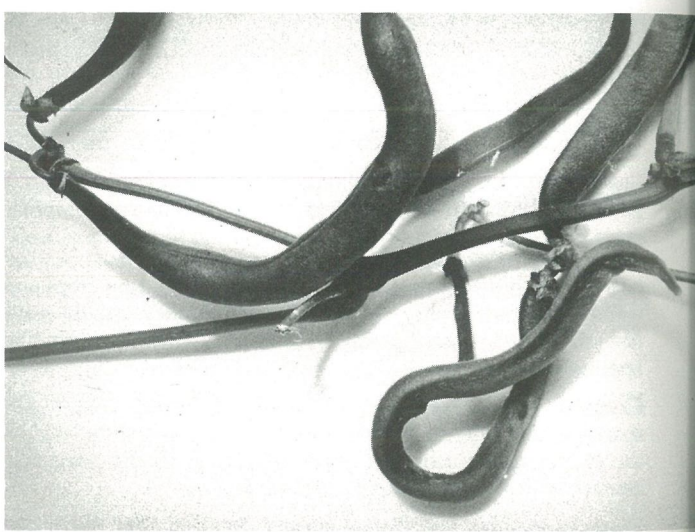
Plants attacked The dwarf French bean appears to be the only edible legume which suffers commercial injury, but other non-edible legumes may be infested.

Description and Life History All thrips are very small insects which have mouthparts adapted for piercing plant surface cells, and almost veinless wings with a relatively large fringe of hairs around the edges. The adult bean blossom thrips is about 1.5 millimetres long and dark brown.

In the autumn, bean flowers usually have some thrips in them; there may be 20 or 30 per flower. Eggs are inserted into soft tissue of flowers, leaves or pods. The young larvae are minute, pale yellow and wingless, but they turn to deep orange-red as they grow older. When full-fed the young thrips drop to the ground and pupate in the soil. The winged adults return to the plant. There are many generations in a season.

Injury The adult thrips enter the flowers as soon as they open, feed on the internal parts, and lay eggs which hatch within a few days. Adults and larvae attack the developing pods which become distorted and are often pimpled and lumpy. The thrips feed in colonies, often producing rusty marks mostly near the stalk ends of the pods. Sometimes a heavy infestation produces rusty blemishes on the undersides of leaves, especially in the area close to the leaf stalks. The margins of the leaves turn down and the foliage has a puckered appearance. In late autumn, bean pods injured by these thrips often develop rot spots which are referred to as 'mildew', and are caused by the fungus *Sclerotinia* sp.

A condition called 'pod twist', resulting from bacterial infection carried by bean blossom thrips, has also been reported (Johnson, 1956).



Bean blossom thrips damage.

Dispersal It is probable that the winged adult thrips may be wind-borne. Plants which are comparatively isolated do become infested. However, it is when new crops are grown near old ones that the invasion becomes rapid and damage is severe.

Control measures

NATURAL Nothing is known of the natural agencies responsible for the regulation of thrips populations, but cold weather and the absence of suitable host flowers must produce the decline in population that occurs in each winter.

APPLIED The application of a routine bean fly control schedule using dimethoate 0.03 per cent (page 226) to crops that would be attacked by bean blossom thrips protects the plants at least until flowering starts. If thrips are obvious when flowering starts, very thorough spraying to penetrate the flowers will be necessary. Maldison 5 per cent dust or 0.06 per cent spray is also effective. Isolation of plantings, or the early destruction of spent crops when a succession of bean plantings has been made, will reduce the possibility of trouble from bean blossom thrips.

Onion thrips *Thrips tabaci*

Young bean plants are sometimes attacked, and may be severely damaged, when soil conditions are dry as onion thrips move on to the beans from other crops or weeds. The older leaves on the bean plants develop a silvery appearance. The undersides of the leaves become shiny and silvery-bronze, and the thrips may be seen both as yellow wingless young and brown winged adults. The leaves turn down at the margins, and may become brown and withered if the infestation is heavy. The adult thrips prefer to feed along the main veins on the upper surfaces of the leaves, where they produce greyish patches of feeding marks that give the leaf a mottled appearance.

Control measures Control is best effected by supplying moisture in the form of irrigation if possible. A good fall of rain will end the trouble. If spraying is necessary, maldison 0.06 per cent, or diazinon 0.025 per cent, or dimethoate 0.03 per cent is very suitable.

Further details of this pest will be found on page 272 under Onion Pests.

HEMIPTERA

Green mirid *Creontiades dilutus*

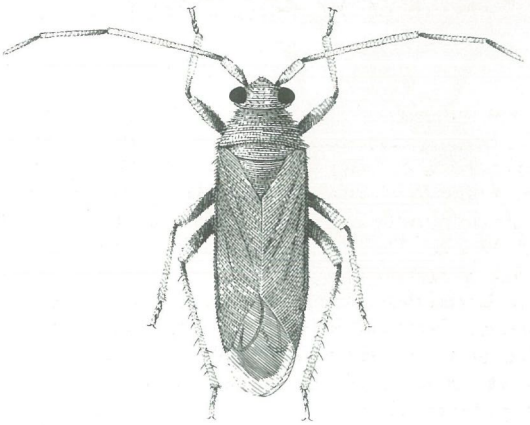
Importance and Distribution Failure of beans to crop in the coastal districts during the spring months has sometimes been due to attack by these small green bugs. They are popularly known as 'blind eye bugs' because they destroy the axillary buds and prevent the plants from producing the blossom-carrying branchlets. The infestation is often brief. In some seasons the bugs have caused severe injury to inland crops in mid-summer.

Conditions for Infestation Green mirid trouble has often occurred in October and November after periods of abnormally low night temperatures in September. It is believed that a check in bean plant growth in September, caused by the cold, makes the crop unusually susceptible to subsequent mirid damage.

Plants attacked The green mirid commonly attacks many vegetable plants. It is also a well-known pest of passionfruit vines – its attack on the growing points may severely stunt the plants. It sometimes attacks peach, nectarine and prune fruits.

Description and Life History The slender adult bugs are about 6 millimetres long and pale green to yellowish green. The wings are translucent and delicate. The legs and antennae are long and slender. The female punctures the soft tissue of a leaf stalk with a sword-like ovipositor to insert the eggs. The eggs hatch in ten to twelve days. The young bugs grow by a series of moults to become adults in about three weeks.

Adult bugs usually become plentiful amongst bean crops in about mid-October. They suck sap, particularly from immature bud tissue in the axils of the stems which is destined to produce flower stalks. By the time the young bugs have hatched, there will be a wider choice of food available to them – blossoms and young pods.



Green mirid. (Length about 6 mm)

Injury The green mirids have a strong preference for succulent young bud tissue, so when they have consumed the bud tissue on beans they usually move on to other plants. They are often common on potatoes just before blossoming, moving to other crops when the potato flowers are finished.

On beans they usually suck the axillary buds that should develop into flower racemes. As a result of the attack the small green buds wither and fall, leaving only the pair of bracts. From this arises the name 'blind eye'. Very small populations of these bugs can be responsible for heavily-reduced yields. The absence of blossom and beans in early December can be puzzling, as the bugs have left the plant by then. It is also true that at that time the plants can recover (if given sufficient moisture) and produce a crop of beans.

Dispersal The adults are strong fliers and may appear with remarkable suddenness in a crop of beans that is at the susceptible stage. Because of their colour and speed of movement, they are difficult to observe.

Control measures

NATURAL The appearance of this pest in a crop is often followed by the arrival of the predatory bug, *Nabis capsiformis* Germar, which kills green mirids, and is thought to be important in limiting their numbers.

APPLIED Bean plants should be watched closely during October and November, and, when the first bugs are seen, the crop should be sprayed thoroughly with maldison 0.075 per cent or, in exceptional cases, with mevinphos 0.07 per cent. Great care must be exercised in using mevinphos as it is highly toxic.

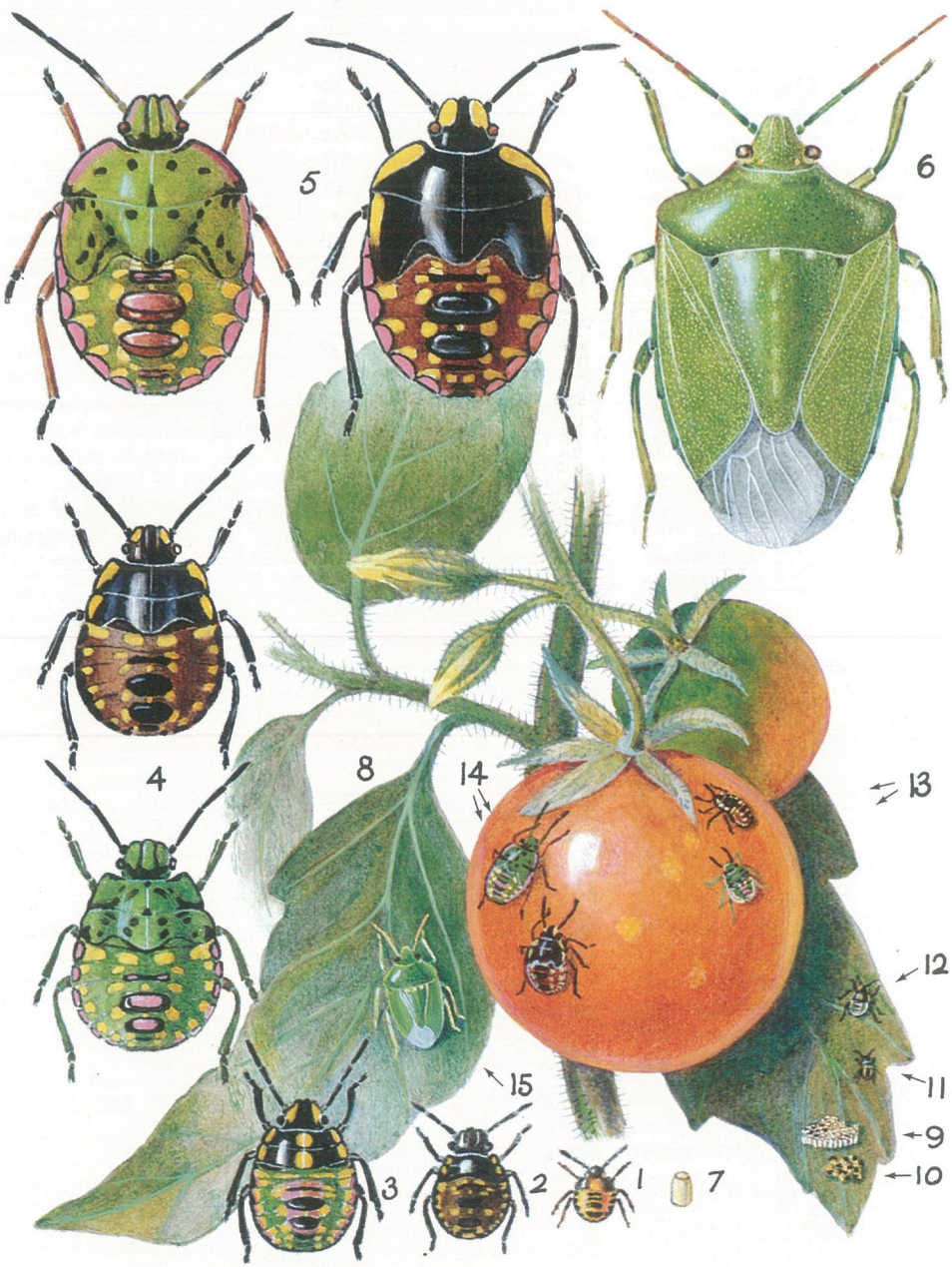
Green vegetable bug *Nezara viridula*

Importance and Distribution This introduced pest was first recorded in New South Wales in 1916 (Froggatt). In the United States it is known as 'southern green stink bug'. It is widely distributed in this State and attacks a variety of crops; in the past, it has severely damaged beans in some seasons. Today the pest has dwindled in numbers and importance since the liberation of several strains of a small wasp parasite which kills the eggs.

Conditions for Infestation Subtropical to temperate conditions suit green vegetable bug. Consequently, coastal areas had earlier and more damaging spring outbreaks than areas further inland. Large populations normally build up in summer and autumn in inland districts.

Plants attacked The most important host plants are beans, lucerne and other legumes, tomatoes, maize, passionfruit, pumpkins and squashes. The bugs prefer to feed on fruit and seeds but may also attack and damage young foliage, notably of potatoes and cabbages. They also feed on a variety of weeds.

Description and Life History The adult is shield-shaped and about 15 millimetres long. It is usually grass green, but



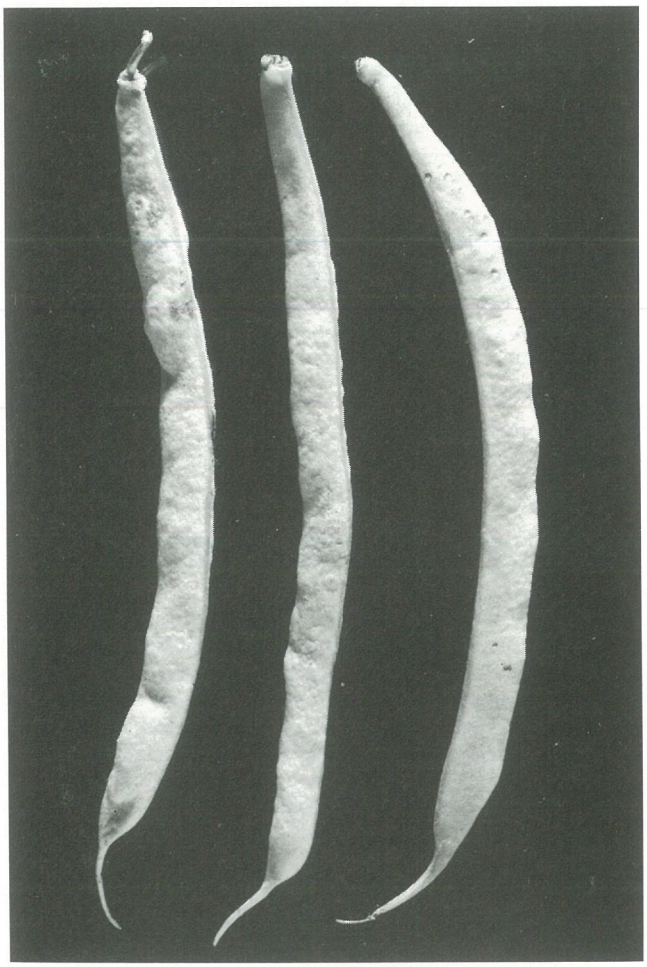
Green vegetable bug
Nezara viridula

1 First-stage nymph; **2** second-stage nymph; **3** third-stage nymph; **4** two colour forms of the fourth-stage nymph; **5** two colour forms of the fifth-stage nymph; **6** adult; **7** an individual egg; all enlarged four times. **8** Tomato plant showing: **9** eggs laid in a cluster; **10** group of first-stage nymphs; **11** second-stage; **12** third-stage; **13** fourth-stage; **14** fifth-stage nymph; **15** adult; all actual size.

overwintering adults become brownish purple during hibernation. They become active at about the end of August, feed on available succulent growth, mate and lay the first batch of eggs. Several generations are bred before the adults begin to hibernate at about the end of May.

The eggs are about 1.25 millimetres long and are laid upright in compact clusters in parallel rows; they are firmly stuck together and on to the surface on which they rest. Eggs laid on beans are usually stuck to the undersides of leaves. Each cluster has about 40 to 80 eggs, and each female may lay four batches. The eggs are pale yellow when fresh, and turn pinkish and then reddish brown with time. They hatch in about five to nine days when the young bugs push the circular caps from the tops of the eggs.

The first-stage nymphs are about 1.5 millimetres long and bright orange with darker markings. They remain clustered near the egg-shells for a day or two. There are five moults between egg and adult. The nymphs are marked with red, green, black and orange. In the fourth and fifth stages there are two distinct colour forms – one is mostly green and the other black, with some intermediate colour forms also. Full development from egg to adult takes five to eight weeks. Huge populations may build up in late autumn, and these may migrate from the plants where they were bred. Detailed description and illustrations of the stages of the life cycle were given by Zeck (1933).



Beans damaged by green vegetable bug.

Injury All stages feed by sucking sap through the needle-like beaks. On beans, the damage is restricted mainly to the pods; they are sucked dry and left shrivelled, distorted and containing only empty shrivelled seeds.

Dispersal The adults fly strongly. They are capable of migration from old hosts to new plants over relatively long distances.

Control measures

NATURAL This bug was reduced to insignificant pest status for many years by the wasp, *Trissolcus basalis* (Wollaston).

In very recent years there have been occasional isolated upsurges of infestation on a variety of crops, but there has been no indication (to date) that this insect will resume its high pest status. The wasp parasite is a shiny black insect, about 1 millimetre long, which was introduced to New South Wales in the mid-1930s. The female wasp lays an egg in the bug egg which then turns black, and within a week a young adult wasp may hatch (Noble, 1937). The first wasps were introduced to Western Australia from Egypt in 1935 by the Department of Agriculture, and then supplied to the New South Wales Department of Agriculture shortly afterwards. At first the egg parasites were unsuccessful in inland districts, but strains introduced later by CSIRO (Wilson, 1960) gave good control in all districts. The newer strains are thought to be better able to survive the colder inland winters.

APPLIED An important first step in the control of green vegetable bug is the elimination of weedy growth from which bug populations could migrate to susceptible crops. Early ploughing-under of spent crops is also important.

If direct control by spraying should be necessary, a material of short residual life should be used because bug damage usually occurs, or threatens to occur, within a few weeks of harvest. Mevinphos 0.07 per cent is satisfactory, but special precautions must be observed because of its high toxicity. Maldison 0.075 is also recommended.

Plant bugs of occasional importance on beans

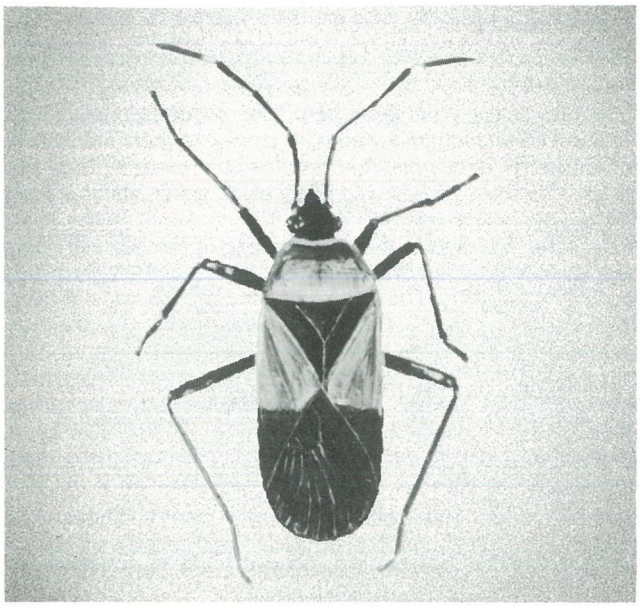
RUTHERGLEN BUG, *Nysius vinitor* These small grey-brown native bugs are about 5 millimetres long and 1.5 millimetres broad. They sometimes swarm on to bean plants and suck the sap of foliage and stems, causing them to wither. They feed on a great variety of plants, and cause losses chiefly when they have bred-up on weeds in the late winter before being forced on to crop plants when the weeds dry off in the spring.

A more detailed account of these bugs is given on page 163 under Grape Pests.

POD-SUCKING BUG, *Riptortus serripes* These slender bugs are 18 millimetres long and reddish brown, with conspicuous yellow-white markings along the body and a small sharp spine on each shoulder. They are native to Australia and sometimes attack beans on the North Coast. They congregate in large numbers on the pods and may quickly suck them dry, reducing the seeds inside to husks.

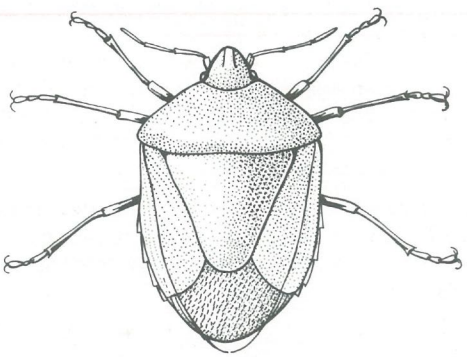
HARLEQUIN BUG, *Dindymus versicolor* These native bugs sometimes invade beans in large numbers after breeding up on

native shrubs or weeds, and suck the pods dry. They are also seen swarming on other crops, tree trunks, fence posts and the sides of sheds. The adult bug is about 12 millimetres long. The head, inner margins of the forewings, and wing tips are black. The thorax and bases of the forewings are reddish orange. The undersurface of the body is yellowish green with red and black markings.



Harlequin bug. (Length about 12 mm)

GREEN STINK BUG, *Plautia affinis* These shield-shaped bugs are about 8 millimetres long, and are mostly green with brown wing covers. They sometimes invade bean crops in large numbers and damage the pods by sucking the juices. They are similar to green vegetable bugs (page 232) but smaller. They give off a very offensive odour when handled. They are more common in the north-western part of the State than elsewhere.



Green stink bug. (Length about 8 mm)

Control measures Control of all the plant bugs mentioned above can be achieved by spraying as recommended for green vegetable bug above.

Passionvine hopper *Scolypopa australis*

The dark brown adults are rather moth-like horny insects about 8 millimetres long. The immature stages are brownish green with a tuft of white feathery hairs rising from the hind end of the body. Both young and adults are very active and skip readily when disturbed. In coastal districts they occasionally attack foliage and stems of beans, causing wilting.

Control measures Control when necessary can be achieved with dimethoate 0.03 per cent spray.

Further details of these bugs will be found on page 189 under Passionfruit Pests.

Vegetable jassid *Austroasca viridigrisea*

These small yellow-green leafhoppers measure about 4 millimetres in length when adult. The young resemble the adults except that they have no wings. They sometimes attack beans in dry weather and may restrict growth severely. Infested plants have irregularly-shaped yellowish flecks on the leaves, especially near the margins. As the damage increases these coalesce to give the leaves a greyish appearance, and growth is stunted. The hoppers occur mainly on the undersides of leaves. When infested bushes are shaken, a swarm of the winged insects will fly out and soon settle again on the foliage. Both adults and nymphs have the characteristic habit of moving with a sideways motion.

Eggs are laid within the tissues of the softer parts of stems. They hatch in ten to twelve days, and the young mature in a further two or three weeks. Populations can build up in a short time. These jassids infest a variety of other crops and weeds.

Control measures A good fall of rain or irrigation will usually reduce the need for chemical control of vegetable jassids. However, spraying with dimethoate 0.03 per cent or maldison 0.06 per cent will give good control.

For further details of this pest see page 297 under Tomato Pests.

Cowpea aphid *Aphis craccivora*

Importance and Distribution Coastal bean crops in New South Wales are sometimes invaded during the spring months by swarms of these greenish black winged aphids. They settle on the growing points of young bean plants (and on other crops as well) and heavily infest the undersurfaces of older leaves. They may interfere considerably with growth, particularly in young plants. Infestation occurs throughout the coastal region, but is most damaging from Gosford northwards. In addition to injury by sap-sucking, the aphids transmit a virus disease of beans.

Conditions for Infestation The aphids migrate from inland areas where they have bred on pasture legumes and other suitable plants. A 'good winter season out west' produces a heavy crop of herbage, especially *Medicago* spp. The aphid population

then increases rapidly. When the pastures hay-off in the spring, the aphids develop wings and fly away. They rise to the upper atmosphere where they are caught by the prevailing winds. When there are prolonged strong north-westerly or westerly winds, the aphids are carried to the coast. At this time the coastal bean crops are often young and aphid attack has a strongly adverse effect, especially if the spring is relatively dry. Even if aphids breed abundantly on the Western Slopes and Plains, they do not reach the coast unless the winds make the journey possible.

Plants attacked The migrant aphids infest many different crop plants and weeds. They are viviparous, and settle on young growth where they quickly produce colonies of active young. They develop well on young beans, cucurbits, peas and apple trees. They seem to have a special preference for summer grass. At other times of the year they may infest broad beans, especially in late summer and autumn.

Description and Life History The adult aphids are greenish black, and about 2.5 millimetres long. The winged aphids settle on the bean plants and produce young which develop as the wingless form. They produce sweet sticky honeydew on which black sooty mould is likely to develop. Reproduction is rapid on many plants, but slow on French beans as aphids become trapped on the epidermal hairs. High populations on beans depend on fresh arrivals of migrant aphids.

Injury The sap-sucking by colonies on the growing points markedly restricts growth, especially in dry weather if irrigation is not available. Leaf distortion may follow the attacks, with the plants becoming stunted. When bean plants with pods on them are infested, the aphids produce dense colonies and sooty mould on the pods which may have to be washed clean for marketing. These aphids also transmit a virus disease, bean yellow mosaic (Grylls, 1972).

Dispersal The spring infestations in bean crops all arise from the original wind-borne migrations and further spread does not take place. Flights of aphids may be expected between mid-September and mid-October, or a little later.

Control measures

NATURAL Many natural enemies attack the aphid colonies, including ladybirds and the larvae of hover flies. When migrations cease, the predators eliminate the colonies. The importance of the aphid pest problem in beans depends on the frequency of arrival of migrant swarms.

APPLIED Spraying with systemic insecticides is effective. Good results can be expected from applying demeton-S-methyl 0.025 per cent or dimethoate 0.03 per cent as a top spray over the upper surface of the leaves. The provision of good growing conditions can offset, to some extent, the injurious effects of the aphids. Irrigation is often of considerable value.

Beans sown in the coastal districts between mid-September and mid-October are likely to be attacked unless drought conditions in Western Slopes and Plains make aphid invasions unlikely. Normally invasions would not be expected after mid-October.

Bean root aphid *Smynthurodes betae*

Bean plants in coastal districts are sometimes infested by an aphid which attacks the roots and underground stems. Usually only an occasional plant in a plot is stunted, but the number is likely to be greater in a dry season than when adequate moisture is available. The aphids are small and globular. They are covered with white mealy material that makes them look like mealybugs; the white material can be seen in the soil beside the infested plants. The aphids produce honeydew which usually attracts ants.

The bean root aphid appears to do only slight damage, except possibly when the bean crop is affected by drought conditions. It is suggested that no measures should be taken against the aphids, but every effort should be made towards good husbandry and attention to the crop.

Greenhouse whitefly *Trialeurodes vaporariorum*

Importance and Distribution This introduced insect was once a rather important pest of beans, especially when they were grown in glasshouses. The successful introduction and establishment of a wasp parasite from New Zealand reduced the whitefly to the status of a minor pest, but there has been an upsurge in numbers in more recent times.

Conditions for Infestation Mild moist conditions are most suitable for the greenhouse whitefly. Such conditions occur in glasshouses and in protected situations with a humid atmosphere in summer and autumn.

Plants attacked Beans, tomatoes, potatoes and cucurbits are commonly attacked, as are many weeds, notably the common sow thistle.

Description and Life History The adult whiteflies are small, delicate, mealy, white insects, about 1.5 millimetres long, with four wings. They congregate on the undersides of the leaves, suck plant juices and secrete honeydew.

Adult females lay eggs, which are yellow at first and later black, on the undersurfaces of young leaves where the four nymphal stages also develop. Pupation takes place in the skin of the last nymphal stage, which later splits for the adult to emerge. There are several generations in a year.

Injury A severe infestation can cause the plants to lose vigour and wilt. The whiteflies produce much honeydew that can cause the pods to become unattractive by encouraging the growth of black sooty mould.

Dispersal The adults are capable of short flights but may be wind-borne over long distances.

Control measures

NATURAL A wasp parasite, *Encarsia formosa* Gahan, was introduced from New Zealand in 1934 (Wilson, 1960). It was established, bred and liberated within New South Wales and was widespread by 1938 (Noble, 1938). It pierces the skin of a fourth-stage whitefly nymph and lays a single egg within the body. A larva hatches from the egg and feeds on the internal organs of the whitefly.

APPLIED Should the need for chemical control arise, maldison 0.06 per cent spray applied to the undersides of the leaves will destroy many of the whiteflies. Repeating treatments at weekly intervals may be necessary.

Greenhouse whitefly. (Length about 1.5 mm)

ARACHNIDA ACARINA

Two-spotted mite *Tetranychus urticae*
Bean spider mite *Tetranychus ludeni*

Importance and Distribution Spider mites are probably the most important pest of beans in New South Wales and can do a great deal of damage in dry seasons. This is more obvious in the coastal districts, where successions of bean crops are commonly grown, than inland. Many different crops are attacked by spider mites. Two-spotted mite and bean spider mite are so similar in habit that they need not be considered separately.

Conditions for Infestation Warm dry weather suits the spider mites best, and adds to the damage they cause by weakening the plants. Infestations do not flourish in cool showery seasons, and a good rainfall will often destroy an important infestation. The availability of plant nutrients may also have some effect. Fruit tree seedlings which are deficient in nitrogen and phosphorus suffer severely from two-spotted mite infestation, but they are also less favourable to the mites than normal plants (Harries, 1966).

Certain spray materials, such as DDT and carbaryl, strongly favour increases of spider mite populations by killing natural enemies, and rapid upsurges in mite populations usually follow their use.

Plants attacked Very many plants are attacked by spider mites – the most severely infested vegetables being beans and cucumbers. The population is carried over the winter mainly by broad-leafed weeds.

Description and Life History In winter in New South Wales, development of spider mites slows down but does not stop. In fairly dry weather, which is expected in coastal districts in spring, infestation increases in intensity during October, November and December. In inland areas the trouble is likely to be at its worst in late summer and autumn.

Typical two-spotted mite adult females. (Length of adult about 0.5 mm)

Typical bean spider mite adult females, with young stage and an egg. (Length of adult about 0.5 mm)

A spider mite
Tetranychus sp.

1 Underside of leaf showing eggs; **2** six-legged larvae and eight-legged nymphs; **3** adult mites; all enlarged thirty times. **4** Bean plants injured by spider mites; actual size.

The small round translucent eggs of the spider mites are laid on the undersides of leaves, usually close to veins. They hatch in a few days. These youngest mites, called 'larvae', are almost colourless but soon become greenish brown. They moult from this six-legged larval stage to the eight-legged stage called 'nymphs', and finally to adults about 0.5 millimetre long. All stages – eggs, larvae, nymphs, adults, empty egg-shells and skins – can be seen with a hand lens on the undersides of leaves under fine webbing. Adults of two-spotted mite are greenish and adults of bean spider mite are red. When plants become badly infested they turn yellow and growth ceases. The mites swarm to the topmost parts of the plants. Web production is stimulated, and the plants become enmeshed in fine webbing.

Adult female mites may lay up to 70 eggs at a rate of a few eggs per day. The males are smaller than the females. Time of development from egg to adult may be seven to eleven days in summer, and there are many generations per year. Infestation usually begins on the lower leaves of beans and progresses upwards. Young adult females move up to the nearest new leaf to lay their eggs, but after that they stay on the one leaf.

Injury The first sign of injury on the plant is the appearance of greyish spots peppered over the leaves. The spots soon coalesce and the leaves become grey all over. The undersurface of the leaf will be covered with webbing and mites, and the surface has a bronzed look. The leaves yellow and wither from the edges; the most heavily infested fall, leaving the plant with only the top green and the lower part bare of leaves. Mature beans on an infested plant will have a greyish appearance, and be tough and lack crispness.

Bean plants heavily infested by spider mites.

Dispersal New plantings of beans are usually infested from older crops or from weeds. The spider mites may be carried by wind, on plant fragments, or by insects and birds. Man is probably one of the most important agents of spread; mites travel on clothing or on implements of cultivation, especially when the machines go through infested crops or weedy headlands. Individual mites do not seem to be readily wind-borne. Colonies have been seen to breed rapidly on a bean plant, and kill the plant or hasten its death. The mites then die on the leaves, either before or after they have fallen, without apparently making any attempt to migrate, but they may be lifted away in webbing or on leaf fragments by wind.

Control measures

NATURAL Many natural enemies keep the numbers of spider mites under control. The most important is the small ladybird, *Stethorus* sp., of which both adults and larvae eat the mites. Others are lacewing larvae, predacious thrips and predacious mites.

APPLIED Attack by spider mites can, to a large extent, be avoided by early and thorough land preparation to eliminate weeds, and the provision of wide weed-free headlands. It is important to plough old bean crops under thoroughly, as soon as they are finished and to avoid, if possible, planting new crops close to the sites of old ones.

Sulphur dust is effective. Two or three applications at intervals of a week are required to contact the young mites hatching from eggs. Demeton-S-methyl 0.025 per cent, or dicofol 0.04 per cent, or dimethoate 0.03 per cent is also effective, although there is some evidence of resistance to these sprays. The spray must be applied to wet the undersurfaces of leaves.

A flat mite *Brevipalpus* sp.

In coastal districts of New South Wales foliage and stems of bean plants, and occasionally pods, become rusty brown with a smooth and slightly shiny look, especially at the junctions of leaf blades with stalks. No webbing is present, but close examination shows small, flat, shield-shaped, reddish brown, sluggish mites. They are almost hairless and have thick stubby legs. The tiny eggs, which are usually laid near the main veins on the undersides of leaves, are oval and bright red.

Damage is uncommon but, where it does occur, will show up in the warmest part of the year, most commonly on the North Coast.

Control is achieved by the methods recommended above for spider mites.

CHILOPODA SCUTIGEROMORPHA

Garden symphylid

A small symphylid centipede has been recorded attacking beans on the Central Coast of New South Wales in early spring and has also damaged asparagus at Cowra. The fully grown centipedes are white, 9 millimetres long and about 1 millimetre thick. They are delicate and avoid light; when exposed, they move rapidly back into the soil. It may be the garden symphylid, *Scutigerella immaculata* (Newport), which can be a serious pest of vegetables in the Northern Hemisphere (Metcalf, Flint and Metcalf, 1962).

Little is known of the suitable conditions for this pest in New South Wales. Damage reported on beans comprises tunnelling in underground stems and seed leaves, and the destruction of the primary roots during germination.

A symphylid. (Length about 9 mm)

MOLLUSCA
GASTROPODA SIGMURETHRA

Common garden snail	*Helix aspersa*
Reticulated slug	*Deroceras reticulatum*
Brown slug	*Deroceras caruanae*
Black-keeled slug	*Milax gagates*

Beans and other vegetables on low-lying ground or beside weedy drains are often damaged by snails and slugs, especially when wet weather follows a dry period. The foliage is chewed in a ragged manner with the main veins usually left untouched. Glistening slime trails are left over the foliage. The snail and slugs which attack crop plants are all introduced species. *Deroceras reticulatum, D. caruanae* and *Milax gagates* are commonly involved (van Regteren Altena and Smith, 1975).

These gastropods are able to stay dormant when dry, but after rain they become very active in search of food both at night and in dull weather by day. They are hermaphrodites, that is each individual has both male and female sex organs. They lay eggs in clusters just under the soil surface.

Control measures Bordeaux mixture spray at 250 grams bluestone – 250 grams lime – 100 litres water strength, plus 1 per cent white oil gives good protection, killing young snails and slugs but acting largely as a repellent and preventing further attack for a time.

Clean cultivation and elimination of shelter are important first steps. The snails and slugs thrive where there is debris.

Metaldehyde or methiocarb baits will kill large numbers if provided when conditions encourage the pests to feed. The baits should be put out in the early evening and placed on the ground, not on the plants.

Land known to be infested before planting can be cleared of these pests by enclosing five or six Khaki Campbell or Indian Runner ducks per hectare.

Snails are discussed more fully on page 82 under Citrus Pests.

Beetroot, silver beet and rhubarb pests

Beetroot can be grown successfully in most parts of New South Wales. For the fresh vegetable trade it is better to grow it close to the main markets, so most of the bunched beetroot is supplied by market gardens around Sydney and Newcastle, whilst the crop for canning is mainly produced at Cowra. Beetroot is sown at any time between early spring and March, and matures in ten to twelve weeks. Irrigation is essential for crops sown in summer, and is always used for crops in inland areas.

Silver beet, also known as 'spinach beet' or 'Swiss chard', is grown commercially on a limited scale in intensively-cultivated market gardens, and in home gardens. It is biennial and, when sown in spring, will usually not run to seed until the following spring. Seed is sown in coastal districts from July to March, in inland districts from August to February, and on the tablelands from September to early January.

Rhubarb is grown in market gardens near major cities and is a popular vegetable in home gardens. Sowing is done in the spring, but crowns may be set out between September and March.

This group of plants is relatively free from pests, although several general and incidental pests may sometimes be of importance. The only specific pests are the beet webworm and the beet leaf-miner.

It is most important that any insecticides used on plants with edible foliage should have short residual activity.

An account is given on pages 240 to 243 of the pests of beetroot, silver beet and rhubarb listed below.

ARTHROPODA
INSECTA LEPIDOPTERA

Beet webworm	*Hymenia recurvalis* (Fabricius)
Cutworms	*Agrotis* spp.
Cluster caterpillar	*Spodoptera litura* (Fabricius)
Cabbage white butterfly	*Pieris rapae* (Linnaeus)
Loopers	*Chrysodeixis* spp.

DIPTERA

Beet leaf-miner	*Liriomyza chenopodii* (Watt)

COLEOPTERA

African black beetle	*Heteronychus arator* (Fabricius)
Vegetable weevil	*Listroderes obliquus* Klug
Flea beetles	Halticinae
Fuller's rose weevil	*Asynonychus cervinus* (Boheman)

	HEMIPTERA
Green vegetable bug	*Nezara viridula* (Linnaeus)
Green stink bug	*Plautia affinis* Dallas
Harlequin bug	*Dindymus versicolor* (Herrich-Schäffer)
Rutherglen bug	*Nysius vinitor* Bergroth
A dink bug	*Creontiades* sp.
Green peach aphid	*Myzus persicae* (Sulzer)
Potato aphid	*Macrosiphum euphorbiae* (Thomas)

	ORTHOPTERA
Black field cricket	*Teleogryllus commodus* (Walker)

ARACHNIDA ACARINA

Broad mite	*Polyphagotarsonemus latus* (Banks)
A rust mite	Eriophyidae
Spider mites	*Tetranychus* spp.
Red-legged earth mite	*Halotydeus destructor* (Tucker)
Blue oat mite	*Penthaleus major* (Dugès)

MOLLUSCA

GASTROPODA SIGMURETHRA

Common garden snail	*Helix aspersa* (Müller)
Reticulated slug	*Deroceras reticulatum* (Müller)
Brown slug	*Deroceras caruanae* (Pollonera)
Black-keeled slug	*Milax gagates* (Draparnaud)

ARTHROPODA

INSECTA LEPIDOPTERA

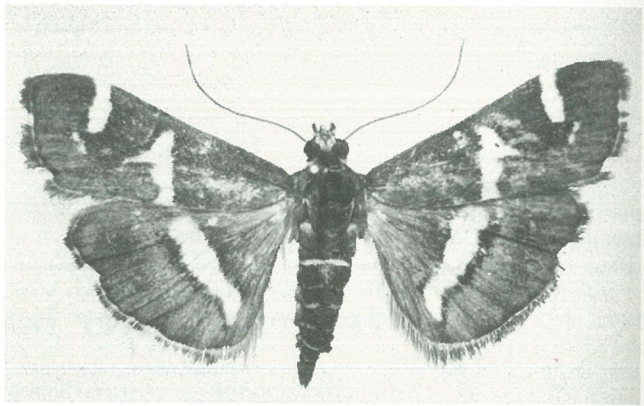
Beet webworm *Hymenia recurvalis*

Importance and Distribution Beet webworm, an introduced insect, is now widely distributed. It can cause severe damage to beet, but it does not appear in large numbers every year, and, when it does so, it is quickly recognized and may readily be controlled.

Conditions for Infestation Warm moist conditions, favouring the growth of weed hosts, are likely to result in an early build-up of pest numbers and an attack on the beet crop.

Plants attacked Beetroot and silver beet, weeds – such as fat hen, *Amaranthus* sp., and pigweed – and saltbush are hosts of this moth.

Description and Life History The moths may become very numerous in late summer, and often swarm to lights. They are about 20 millimetres across the outspread wings, and are generally brown with two incomplete white bands across the forewings and a similar complete band across the hindwings. The hindwing band is continuous with one of the bands on the forewings. They lay eggs in small clusters on the lower sides of leaves, usually beside a vein. The eggs hatch in four or five days. The spindle-shaped larvae are creamy white at first, but grey-green to black markings develop later, with a black line down the middle of the back. The full-grown larva is about 18 millimetres long, and is commonly stretched out so that two prolegs on the last abdominal segment are plainly visible. Large numbers may be on a plant, feeding on the undersides of leaves but leaving the cuticle of the upper surface intact with the appearance of windows. Later the foliage is nearly destroyed – reduced to a network of veins and 'windows' which are heavily webbed, with the inclusion of many pellets of greenish brown excreta. Sometimes, when a beet plant is very heavily infested, the late-stage larvae will go down to graze on the fleshy tissues at the top of the root. Full-fed grubs descend to the soil and pupate just



Beet webworm adult. (Wingspan about 20 mm)

Beet webworm larva on a silver beet leaf. (Length of larva, when fully developed, about 18 mm)

under the surface. The cocoons are about 12 millimetres long, oval in shape, and covered with grains of soil. The moths emerge in about two weeks, and the whole life cycle is completed in about a month.

Injury Heavy infestation may destroy a plant, and lighter infestation can make silver beet leaves look very unattractive with webbing and excrement. Maturing beetroot may be chewed around the crown of the plants where very numerous beet webworm caterpillars are attacking the foliage.

Control measures

NATURAL Beet webworm may be abundant in one year and uncommon for several seasons, possibly due to significant attack by natural enemies.

APPLIED Destruction of the host weeds in the neighbourhood of beet crops early in the season will reduce the chances of a population build-up. Should direct control become necessary, spraying with carbaryl 0.1 per cent or mevinphos 0.07 per cent has been shown to be effective, but several applications may be necessary. Special precautions must be observed when spraying with mevinphos because of its high toxicity.

Cutworms *Agrotis* spp.

Cutworms are always likely to nip off young plants shortly after they have been set out or have come above ground. The caterpillars attack during the night and the remains of plant tops lying on the soil is a sign that they have been at work. This can usually be confirmed by searching in the soil at the base of the plant to see if one or two cutworms are hidden there.

This pest is described and control measures are discussed on page 221 under Bean Pests.

Cluster caterpillar *Spodoptera litura*

These caterpillars in their young stages feed in clusters and graze patches of surface tissue, usually on the undersides of leaves. The large caterpillars can chew big holes in the leaves. Silver beet and, occasionally, beetroot and rhubarb are attacked in late summer and autumn in coastal districts, but the pest is not an important one.

This pest is described and control measures are discussed on page 251 under Cruciferous Pests.

Cabbage white butterfly *Pieris rapae*

The green velvety larvae may attack silver beet on rare occasions, but they are not a significant pest of this crop.

This pest is described on page 249 under Cruciferous Pests.

Loopers *Chrysodeixis* spp.

Silver beet is often infested by loopers in spring or autumn when the weather has been cloudy and humid. The pale green caterpillars feed on the backs of leaves, make large irregular holes, and deposit rather large barrel-shaped pellets of excrement.

Loopers have been described and control measures discussed on page 223 under Bean Pests.

DIPTERA

Beet leaf-miner *Liriomyza chenopodii*

Infestation of silver beet, and sometimes beetroot, by these leaf-mining fly larvae has occurred in both coastal and inland areas. They tunnel in leaf stalks and veins and, when numerous, may cause the leaves to wither and die. They were described from specimens bred on spinach, wallflower and chickweed (Anon, 1947). Kleinschmidt (1970) has suggested that the species infesting beet may be *Haplomyza caulophaga* Kleinschmidt.

The adult fly is about 1 millimetre long, and grey with yellow head and pale yellow body markings. The abdomen is black with transverse yellow bands. This fly is closely related to the bean fly. Circular raised corky scars mark the points at which eggs were laid in the leaf stalk. The white maggots mine in the veins and stalks, making thread-like lines which enlarge to conspicuous tunnels as the maggots grow. If leaves are not killed, their value may be reduced by the scars and mines.

When full-fed the maggots change within the tunnels to brown barrel-shaped pupae about 2 millimetres long.

Control measures Spraying at weekly intervals with dimethoate 0.02 per cent beginning at the first sign of infestation, should be effective in controlling this pest.

COLEOPTERA

African black beetle *Heteronychus arator*

The fleshy bases of rhubarb crowns, when set out in infested land, are sometimes chewed at ground level by black beetles. Maturing roots of beet have sometimes been attacked by black beetles moving in from adjoining breeding areas.

Details of life history, habits and methods of control are discussed on page 295 under Tomato Pests.

Vegetable weevil *Listroderes obliquus*

Late-sown beetroot and silver beet may be attacked in late autumn and winter by larvae of the vegetable weevil, when these crops are put in land that was recently under weeds. The centres of the young plants are chewed out by the small, yellow or green, legless grubs. Later the grubs feed on the undersurfaces of leaves, producing a shot-hole effect.

Details of life history and control are given on page 253 under Cruciferous Pests.

Flea beetles Halticinae

Several species of flea beetles have been recorded attacking rhubarb in New South Wales. These small beetles jump readily which is the origin of their common name. They make small holes in the foliage, which may appear to have been riddled by fine shot. If it is necessary, spraying with carbaryl 0.1 per cent should give effective control.

Flea beetles are described on page 284 under Potato Pests.

Fuller's rose weevil *Asynonychus cervinus*

These weevils attack many different plants in late summer or autumn, and often damage rhubarb. They nibble pieces out of the edges of leaves, producing a saw-tooth appearance. The damage is usually not important. If protection is required, carbaryl used as recommended for flea beetles should be effective.

This weevil is discussed in detail on page 36 under Citrus Pests.

HEMIPTERA

Green vegetable bug *Nezara viridula*
Green stink bug *Plautia affinis*
Harlequin bug *Dindymus versicolor*
Rutherglen bug *Nysius vinitor*

Several plant bugs, including green vegetable bug, green stink bug, harlequin bug and Rutherglen bug, may attack silver beet and, to a lesser extent, beetroot and rhubarb.

They are all described in detail on page 232 under Bean Pests and on page 163 under Grape Pests.

A dink bug *Creontiades* sp.

Rhubarb crops around Sydney are sometimes damaged rather severely by this bug which is slender, pale green and rather rectangular in shape. It is an active insect, with long legs and antennae, which sucks the sap at the growing point and may cause serious distortion or stunting of growth. It is quite possible that this bug is the green mirid *C. dilutus* but this has not been resolved. It may be controlled by the methods described for that pest on page 231 under Bean Pests.

Green peach aphid *Myzus persicae*
Potato aphid *Macrosiphum euphorbiae*

These two aphids sometimes swarm on silver beet and rhubarb, and may cause serious wilting. They also produce unsightly honeydew. Infestation may be expected in cool dry weather in spring and in late autumn. They attack a great variety of crops.

For control, reference should be made to page 285 under Potato Pests.

ORTHOPTERA

Black field cricket *Teleogryllus commodus*

This insect sometimes damages silver beet and beetroot by chewing the tops in autumn. It is likely to be destructive in wet seasons. Crickets sometimes gnaw the young plants at ground level and cut them off.

This insect and its control are described on page 257 under Cruciferous Pests.

ARACHNIDA ACARINA

Broad mite *Polyphagotarsonemus latus*

This mite commonly attacks silver beet and rhubarb during late summer and autumn in coastal areas, and may cause considerable reduction in vigour. The leaves and stalks become rusty or

silvery-looking, and there may be considerable distortion; the injury is sometimes similar to the effect of 2,4-D weedicide. The younger inner leaves are the most affected. Broad mites attack many other plants; citrus fruits, especially lemons, are sometimes severely injured by them.

Control measures Spraying with dicofol 0.04 per cent to make contact with both sides of the younger leaves or dusting with sulphur should give satisfactory control.

Broad mite is described in more detail on page 79 under Citrus Pests.

A rust mite — Eriophyidae

Huge numbers of yellow worm-like mites often infest the lower surfaces of rhubarb leaves during summer and autumn. The leaves develop a brown or bronze coloration and a slightly shiny look and may curl downwards at the edges, later withering and drying out.

Control measures Dusting with sulphur should be effective if the control of an infestation is necessary.

Spider mites — *Tetranychus* spp.

During very hot weather spider mites may attack beetroot, silver beet and rhubarb, especially if the crop is growing near old beds of beans or cucumbers that were infested earlier. The plants lose vigour and have a grey appearance. Closer examination shows the speckled foliage and the fine grey webbing on the undersides of the leaves. Under the webbing are the tiny spider-like mites and their round eggs.

Spider mites are described more fully on page 236 under Bean Pests.

Red-legged earth mite — *Halotydeus destructor*
Blue oat mite — *Penthaleus major*

These earth mites can damage beet in autumn, winter and spring in inland districts. They are discussed more fully on page 275 under Pea Pests.

MOLLUSCA
GASTROPODA — SIGMURETHRA

Common garden snail — *Helix aspersa*
Reticulated slug — *Deroceras reticulatum*
Brown slug — *Deroceras caruanae*
Black-keeled slug — *Milax gagates*

These pests are likely to be a considerable nuisance, especially after prolonged wet weather. Not only do they do extensive damage by chewing foliage, but they may hide in the leaves where they, and their excrement, are repellent to the buyer of silver beet or rhubarb.

Further details will be found on page 82 under Citrus Pests and on page 239 under Bean Pests.

Carrot, parsnip, celery and parsley pests

In New South Wales carrots are in demand at all times of the year. The crop is not difficult to grow as it can be fitted into other cropping programmes and thrives under many different conditions. Carrots are therefore grown in many parts of the State. Crops are generally irrigated, except for many on the coast and Northern Tablelands.

A variety of pests may infest carrots, many being of local significance only. Wise land preparation can ensure freedom from vegetable weevil damage, and care in selecting the right variety and time of planting will make an important contribution towards avoiding loss from carrot aphid.

Parsnips, celery and parsley are minor crops and the control measures used against their pests are broadly the same as for carrots. Good farming practices minimize pest problems in the crops. Irrigation will generally ensure freedom from damage by pests such as spider mites and jassids.

An account is given on pages 244 to 248 of the pests of carrots, parsnips, celery and parsley listed on the next page.

ARTHROPODA

INSECTA — LEPIDOPTERA

Lucerne leaf-roller	*Merophyas divulsana* (Walker)
Light-brown apple moth	*Epiphyas postvittana* (Walker)
Cutworms	*Agrotis* spp.

HYMENOPTERA

Parsnip seed wasp	*Systole* sp.

DIPTERA

Celery fly	*Melanagromyza apii* Hering

COLEOPTERA

White fringed weevil	*Graphognathus leucoloma* (Boheman)
Vegetable weevil	*Listroderes obliquus* Klug
Wireworms	Elateridae
False wireworms	Tenebrionidae

HEMIPTERA

Carrot aphid	*Cavariella aegopodii* (Scopoli)
Cowpea aphid	*Aphis craccivora* Koch
Root mealybug	*Rhizoecus falcifer* Künckel d'Herculais
Fennel aphid	*Dysaphis foeniculus* (Theobald)
Green mirid	*Creontiades dilutus* (Stål)
Rutherglen bug	*Nysius vinitor* Bergroth
Vegetable jassid	*Austroasca viridigrisea* (Paoli)

ARACHNIDA — ACARINA

Spider mites	*Tetranychus* spp.

MOLLUSCA

GASTROPODA — SIGMURETHRA

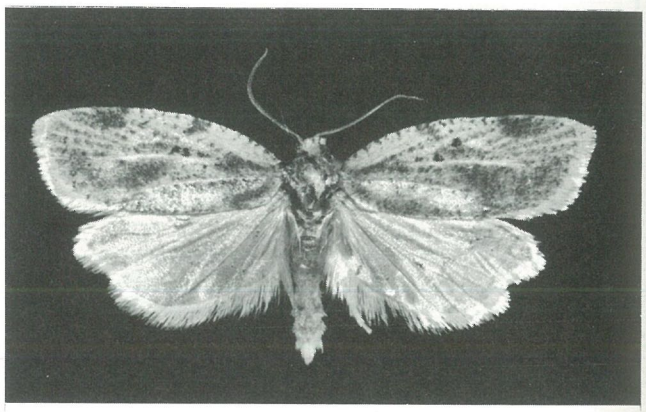
Common garden snail	*Helix aspersa* Müller
Reticulated slug	*Deroceras reticulatum* (Müller)
Brown slug	*Deroceras caruanae* (Pollonera)
Black-keeled slug	*Milax gagates* (Draparnaud)

ARTHROPODA

INSECTA — LEPIDOPTERA

Lucerne leaf-roller *Merophyas divulsana*
Light-brown apple moth *Epiphyas postvittana*

These two moths are discussed together as their appearance, life histories, habits and attack on carrots are similar. The adults are both bell-shaped moths but differ in size with lucerne leaf-roller being 13 millimetres across the outspread wings and light-brown apple moth 18 millimetres. Lucerne leaf-roller adults are yellowish with darker markings, while light-brown apple moths are buff-coloured. Lucerne leaf-roller larvae reach a length of about 10 millimetres and those of light-brown apple moth about 18 millimetres. They are slender green caterpillars that typically wriggle backwards when disturbed. They feed on foliage and web the leaves together. The pupae are formed in flimsy cocoons in a folded leaf. The eggs are laid in flat clusters on the leaves like groups of tiny fish scales. Damage may occur in both spring and autumn crops, and in some seasons is extensive.



Lucerne leaf-roller adult. (Wingspan about 13 mm)

Control measures If control is considered to be necessary, spraying with azinphos-methyl 0.05 per cent, or carbaryl 0.1 per cent, is suggested.

Light-brown apple moth is described in more detail on page 96 under Apple Pests.

Cutworms *Agrotis* spp.

Young carrot crops are sometimes attacked at night by cutworms which cut through the leaf stalks at ground level. This pest is most likely to be troublesome where the crop is sown in weedy land worked up quickly before sowing.

Control measures Spraying with endosulfan 0.07 per cent is recommended to control the infestation.

Cutworms and their control are described in more detail on page 221 under Bean Pests.

HYMENOPTERA

Parsnip seed wasp *Systole* sp.

Ripening parsnip seed in the umbels is pierced by tiny holes through which the very small wasps emerge after their larvae have eaten out the contents of the seed.

Careful removal and burning of all old parsnip seed heads and plant residues, and avoiding growing parsnip seed in the area for at least one season, are suggested.

DIPTERA

Celery fly *Melanagromyza apii*

Occasional trouble has been experienced in the market garden areas around Sydney from the attack of a small maggot which feeds in celery stalks, and bores its way down to the base of the plant. The leaf stalk yellows and remains stunted, or may die if there are enough maggots present in the stem. Little is known of the life history of this fly, but it probably parallels that of the bean fly described on page 226 under Bean Pests. It seems that infestation is most likely to occur when successions of celery crops are grown in the same area.

If control should be necessary, the materials and type of spray programme recommended for bean fly are suggested.

COLEOPTERA

White fringed weevil *Graphognathus leucoloma*

Carrots and parsnips, sown in land which has been under lucerne or clovers, are sometimes attacked by the larvae of white fringed weevil. Considerable damage has been seen on the Northern Tablelands under those circumstances. The grubs feed mainly in autumn or spring, but it is usually in about November that damage becomes evident as the larvae reach full size – about 12 millimetres long. The injury may range from a few patches chewed in the root to severe furrowing of the root going into the core. Seedlings may be killed, usually in patches throughout the field. On seedlings, the base of the stem and tap-root may be gnawed down to a depth of several centimetres.

Control measures Control depends on recognizing the possibility of this attack, and then making sure that the area to be planted to the root crop is worked up from pasture well beforehand in order to starve out the larvae. Growing a cereal crop to be ploughed in is a very good practice. The advantages are that weeds are killed and their regrowth suppressed, organic matter is provided for the soil, and the cereal does not support the weevil.

White fringed weevil is described in greater detail on page 281 under Potato Pests.

Carrot damaged by white fringed weevil larvae.

Vegetable weevil *Listroderes obliquus*

This introduced weevil is found throughout New South Wales. Larvae and adults can cause serious damage to carrots, parsnips and celery. Autumn-sown crops of carrots are more susceptible to damage than earlier ones in which the plants are fairly large at the onset of winter. Weevil larvae feeding in the winter can be very destructive to young plants. In spring, most damage is from the adult beetles that are abundant from late August to November. There are many suitable hosts including various vegetables, most garden flowers, and weeds such as capeweed and marshmallow.

Damage to young carrots first becomes evident in late autumn or early winter; the plants stop growing. Examination shows that the centres have been chewed out and the growing points destroyed. The tiny legless grubs are pale green or yellow, and will

be found in the damaged centre or in the soil under the plants. As the larvae grow larger they attack the foliage, and the crown as the root develops, making holes and furrows. Towards the end of winter the larvae are full-fed. They go down into the soil and pupate in earthen cells, before emerging as the new adults. These are active during the spring, feeding voraciously at night. They attack both tops and roots, and may spoil the roots by gouging out large craters in the flesh, especially around the crown. In summer they become inactive, sheltering in the soil and in plant debris. In late autumn they lay their eggs.

Control measures Control is best achieved by planting carrots in well-fallowed land that has been kept free from weed growth for some time. Better still, grow a crop which is unsuitable for vegetable weevil – beans, peas or a cereal – before the carrots. This is especially important if the carrot crop is sown in late summer or autumn.

Where land is suspected of harbouring vegetable weevils, spraying with DDT 0.1 per cent or baiting with lindane-bran mixture has been successful in controlling them.

Another form of attack is the migration of adult weevils to the crop in spring from nearby weedy land. This can be prevented by cultivating the weedy areas in winter to destroy weeds and weevils.

It has been noted that Osborne Park carrots are much less attractive to vegetable weevil than the variety Red Cored Chantenay.

This weevil is described in more detail on page 253 under Cruciferous Pests.

Wireworms — Elateridae
False wireworms — Tenebrionidae

Wireworms and false wireworms breed in pasture land. When the pasture is ploughed up and sown to carrots, these larvae turn to the root crop for food. They chew patches of the flesh and bore narrow holes deep into the roots, sometimes even right through.

Control measures Control by direct means is difficult and not often justified. Avoiding the trouble by a long fallow, with thorough working of the fallow before the planting of susceptible crops, is the best method of handling the problem.

More information will be found on page 256 under Cruciferous Pests.

Carrot aphid — *Cavariella aegopodii*

Importance and Distribution Carrot aphids can cause severe injury as a result of their feeding, but they also carry an important virus disease, carrot motley dwarf, that can cause severe losses. They are likely to be found anywhere in New South Wales that carrots are grown. Most heavy infestations are reported from the Central Coast, Central Tablelands and Murrumbidgee Irrigation Area. The attacks are less important in the north. The aphid survey of Hughes *et al* (1964) showed the carrot aphid to be uncommon in Queensland, but abundant in Victoria and Tasmania.

Conditions for Infestation Cool dry weather suits the aphid as well as retarding the crop. Infestations are more important in winter than in warmer weather.

Plants attacked Carrots and the related crop plants are all susceptible to attack, and so are weeds belonging to the same botanical family.

Description and Life History Winged and wingless forms of the aphid are found together on the plants. They vary in colour through green, yellow and brown to almost red. They reproduce by giving birth to active young, as do most aphids. The time taken to develop from birth to the adult stage may be as short as ten days. Periodically the colonies produce winged forms that fly away seeking new host plants. This can happen at any time of year, but is more frequent in autumn and in late spring than at other times. The aphids produce copious quantities of honeydew.

Injury The aphids cluster on the undersides of leaves and may completely cover the leaf area. The leaves become curled and buckled, and the plants grow poorly and turn yellow. Carrot plants take on a red tinge. The foliage develops a harsh appearance and is shiny from honeydew.

Dispersal The winged forms allow dispersal to the crop and through the crop from plant to plant.

Control measures

NATURAL The aphids have many natural enemies – ladybirds, hover fly and lacewing larvae – but they tend to be least active in winter when the aphids are most obviously destructive.

Some carrot varieties, notably Chantenay, are more susceptible to injury by the virus disease than others. Osborne Park variety has a good measure of resistance to aphids and to the virus, but is now grown only rarely.

Early sowing, not later than February, allows crops to make good growth before the aphids become abundant. Later-sown crops are likely to be checked in growth in the early stages. In spring later-sown crops tend to escape the worst injury.

APPLIED Good control may be expected from the use of systemic aphicides such as demeton-S-methyl 0.025 per cent, or dimethoate 0.03 per cent.

Cowpea aphid *Aphis craccivora*

Spring-sown carrots may be attacked during September or October in coastal areas north of Sydney and on the Northern Tablelands. The swarms of black aphids suddenly descend on the very young plants. They cluster on the growing shoots and later on the backs of leaves. The winged forms come on the wind from drying pastures further inland and give rise to broods of wingless young that colonize the undersides of the leaves.

Control measures Natural enemies attack the aphids but, if further treatment is thought to be necessary, the infestation should be sprayed with a systemic insecticide such as demeton-S-methyl 0.025 per cent or dimethoate 0.03 per cent.

Carrot crops sown after the middle of October have a good chance of escaping infestation.

Further details of the cowpea aphid are given on page 234 under Bean Pests.

Root mealybug *Rhizoecus falcifer*

Carrots and parsnips are occasionally attacked by this insect, but it is generally of minor importance. Affected plants become yellow and sickly. The root is found to have clusters of small insects covered with white mealy material. Ants are commonly associated with the infestation because of the honeydew produced.

Control is rarely necessary and no satisfactory method has yet been recommended.

Fennel aphid *Dysaphis foeniculus*

This pest occasionally attacks carrots, but it is of only slight importance. Infested plants are usually surrounded by mounds of small brown ants. On the roots there are colonies of small grey aphids which, in cloudy weather, may come up from the ground and infest the plant crowns and leaf stalks. The injury results in yellowing and stunting.

Control measures Control is rarely either necessary or feasible. While they are above ground the aphids may be killed by the application of sprays of demeton-S-methyl or dimethoate.

Green mirid *Creontiades dilutus*

These slender, pale green or yellow, active bugs are about 6 millimetres long and may sometimes be seen on the umbels of seed crops in the spring in coastal areas. Sucking of the sap from buds and flowers cause them to fall so the seed heads fail to set seed. Carrots and parsnips are not commonly grown for seed on the coast so this pest is of only minor importance.

Further information is given on page 231 under Bean Pests.

Rutherglen bug *Nysius vinitor*

On carrots, swarms of these bugs can produce damage that looks like scorching by fire. Severe stunting of growth follows and, if seed production is the object, it may be completely prevented. All stages of the bug may invade a carrot crop, but at the stage when carrot seed might be in production, the adults are most likely to be responsible for the attack. The bugs suck out the seed sap and the developing seed dries up.

Control measures Maldison 0.06 per cent or mevinphos 0.05 per cent spray has given good control. Mevinphos must be applied with great care because of its high toxicity.

This pest is discussed in more detail on page 163 under Grape Pests.

Vegetable jassid *Austroasca viridigrisea*

Carrots, parsnips and celery grown without irrigation are sometimes injured in hot weather by these leafhoppers. They are small (4 millimetres long) and yellowish green. They feed and shelter on the undersides of leaves and, when disturbed, fly out in a cloud to return and settle in a short time. When avoiding danger on the plant they move with a characteristic sideways action. Their repeated punctures may make the foliage grey or yellow.

Control measures A good fall of rain or irrigation will usually let the plants grow away from the damage. If more protection is needed, spraying with dimethoate 0.03 per cent or maldison 0.06 per cent will give good control.

Jassids are described in more detail on page 297 under Tomato Pests.

ARACHNIDA ACARINA

Spider mites *Tetranychus* spp.

Severe spider mite infestation sometimes develops on carrots and related plants. It is most likely to happen to non-irrigated crops in hot weather when they have been planted too close to old spider mite-infested crops such as beans. The carrots become grey-speckled on the lower leaves; the leaves turn yellow and then brown. The undersides of the leaves are covered with fine webbing amongst which can be seen the tiny green or red spider mites and their eggs.

Spider mites, and control measures against them, are described on page 236 under Bean Pests.

MOLLUSCA

GASTROPODA — SIGMURETHRA

Common garden snail *Helix aspersa*
Reticulated slug *Deroceras reticulatum*
Brown slug *Deroceras caruanae*
Black-keeled slug *Milax gagates*

The brown snail and slugs sometimes damage carrot and related crops, especially in continuously wet weather. They feed on the foliage and leave their glistening slime trails.

Control measures The damage can often be stopped by spraying with Bordeaux mixture plus white oil. Snail and slug baits containing metaldehyde or methiocarb, preferably in pellet form, can also kill large numbers of the pests. They should be spread amongst the infested plants in the evening.

Further details will be found on page 82 under Citrus Pests and on page 239 under Bean Pests.

Cruciferous pests

Cruciferous or cole crops are important in New South Wales, and they are cultivated in many regions at varying times of year. They include cabbage, cauliflower, Brussels sprouts, broccoli, swede, turnip and radish. Although these are essentially cold climate crops, cabbages and, to a lesser extent, cauliflowers can be grown in almost every district in the State. The main growing areas are Bathurst, Windsor-Richmond, Maitland-Singleton, Robertson and Cowra.

Most crops are grown and harvested during the autumn and winter months, but some are available through most of the year. Pest control is of prime importance in the warmer weather, and regular treatments at short intervals are required. Whenever the crop is grown some measures for control of the common pests, such as cabbage moth, cabbage white butterfly and aphids, will usually be necessary. The practice of sound farming principles, such as the early destruction of spent crops, early and thorough preparation of the land to be planted and the siting of seedbeds well away from possible sources of infestation, is an important prerequisite for success.

An account is given on pages 249 to 259 of the pests of cruciferous crops listed below.

ARTHROPODA

INSECTA — LEPIDOPTERA

Cabbage white butterfly	*Pieris rapae* (Linnaeus)
Cabbage moth	*Plutella xylostella* (Linnaeus)
Cluster caterpillar	*Spodoptera litura* (Fabricius)
Cabbage-centre grub	*Hellula hydralis* Guenée
Loopers	*Chrysodeixis* spp.
Budworms	*Heliothis* spp.
Cutworms	*Agrotis* spp.

DIPTERA

Onion maggot	*Delia platura* (Meigen)
A leaf-miner	Agromyzidae

COLEOPTERA

Vegetable weevil	*Listroderes obliquus* Klug
White fringed weevil	*Graphognathus leucoloma* (Boheman)
A ground beetle	*Clivina biplagiata* Putzeys
Spotted vegetable weevil	*Desiantha diversipes* (Pascoe)
African black beetle	*Heteronychus arator* (Fabricius)
Striped flea beetle	*Phyllotreta nemorum* (Linnaeus)
Wireworms	Elateridae
False wireworms	Tenebrionidae

THYSANOPTERA

Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

Cabbage aphid	*Brevicoryne brassicae* (Linnaeus)
Green peach aphid	*Myzus persicae* (Sulzer)
Rutherglen bug	*Nyzius vinitor* Bergroth
Green vegetable bug	*Nezara viridula* (Linnaeus)
Harlequin bug	*Dindymus versicolor* (Herrich-Schäffer)

ORTHOPTERA

Black field cricket	*Teleogryllus commodus* (Walker)
Wingless grasshopper	*Phaulacridium vittatum* (Sjöstedt)
Yellow-winged locust	*Gastrimargus musicus* (Fabricius)

ARACHNIDA — ACARINA

Red-legged earth mite	*Halotydeus destructor* (Tucker)
Blue oat mite	*Penthaleus major* (Dugès)

INSECTA LEPIDOPTERA

Cabbage white butterfly *Pieris rapae*

Importance and Distribution This insect, a native of Europe, is now widely distributed throughout the world. It first appeared in Australia in Melbourne in 1939, and in southern New South Wales in 1940. It is an extremely voracious feeder, active throughout most of the year, and the most important pest of crucifers in this State.

Conditions for Infestation The cabbage white butterfly tolerates a wide variety of climatic conditions. It is usually most active in autumn, but may become abundant in spring, and in warmer districts will work through the winter.

Plants attacked The caterpillars feed on all cruciferous crops, garden stocks and wallflower, sometimes mignonette and nasturtium, and weeds such as shepherd's purse and wild mustard.

Description and Life History The butterflies are commonly seen flying in the crop or visiting blossoms nearby. They feed on nectar, and lay their eggs on crucifers. They are yellow-cream, with black tips on the forewings, and have a wingspan

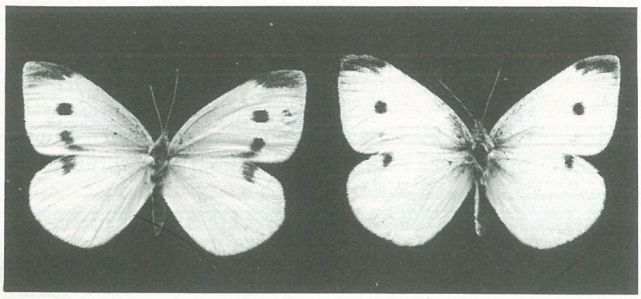
Cabbage white butterfly
Pieris rapae

1 Egg; enlarged ten times.
2 Larva or caterpillar; **3** pupa; enlarged about 2.5 times.
4 Eggs on leaf; **5** larva or caterpillar; **6** pupae attached to plant; **7** adult butterfly; all actual size.

of 4 to 5 centimetres. The female has two black spots on the upper surface of each forewing, while the male has only one spot. Both sexes have one black spot on each hindwing.

The eggs are usually laid on the undersides of leaves. They are spindle-shaped, pale yellow and laid singly, mostly on the outer leaves of a plant. The caterpillars are pale green, and velvety due to a fine hair covering, with faint yellow stripes down the back and along the sides. When young they feed mostly on the undersides of leaves, but when older they are found on both surfaces.

When full-fed and about 3 centimetres long, the larva pupates. It hangs from the plant attached by its tail to a silken pad, while its body is supported by a fine silken girdle around the middle. Sometimes the mature larva wanders away from the plant, so the pupa is attached to some nearby object. The pupa is 18 millimetres long, light grey, yellow or green. In warm weather the eggs hatch in a few days, the larvae feed for two or three weeks, and the pupal stage lasts for two weeks. There are several generations in a year and they generally overwinter as pupae.



Cabbage white butterfly – female at left, male at right. (Wingspan 4 to 5 cm)

Cabbage white butterfly larva. (Length, when fully developed, about 3 cm)

Injury The caterpillars eat out ragged holes in the leaves, up to about 2.5 centimetres across, and feed on the outer leaves of the heart. Heavily infested plants become ragged and stunted, and fouled with dark green pellets of excrement, but no webbing is present.

Dispersal The adults are strong fliers and may be found many kilometres from suitable hosts.

Control measures

NATURAL Three wasp parasites of this pest have been imported – *Pteromalus puparum* (Linnaeus), a parasite of pupae, and *Apanteles glomeratus* (Linnaeus) and *A. rubecula* Marshall, parasites of the larvae (Wilson, 1960). Clusters of parasite cocoons are often seen on the fully grown caterpillars which cease feeding and die. *Pteromalus puparum* also parasitizes the pupae of some other butterflies.

A polyhedrosis virus may kill many of the caterpillars on the plants. These enemies reduce numbers of the pest, but not enough to make other control measures unnecessary.

APPLIED Plants in the seedbed and in the field should be sprayed with diazinon 0.1 per cent, or methomyl 0.045 per cent, or mevinphos 0.07 per cent, or dusted with maldison 5 per cent. It is extremely important to see that the dust or spray covers the undersides of leaves as success depends on killing the young caterpillars – the older ones being less susceptible. Weekly treatments are needed in the seedbeds, and weekly to fortnightly treatments in the field. Note that special precautions must be observed in handling mevinphos because of its high toxicity.

Cabbage moth *Plutella xylostella*

Importance and Distribution This introduced pest, also called the diamond-back cabbage moth, has been known since the early days of New South Wales (Fuller, 1896). Before the late 1940s it was the major pest of crucifers. Since that time it has declined in importance. The reasons for this change are not clear but undoubtedly include competition from the cabbage white butterfly, the general use of DDT which was spectacularly effective against cabbage moth, and the subsequent introduction of parasites.

Conditions for Infestation Cabbage moth tolerates a wide range of climates and occurs throughout New South Wales, but it prefers hot dry districts and is generally more important inland than on the coast. Numbers decline markedly in the winter but generally rise to a high level in late summer.

Plants attacked All types of cruciferous crops, garden flowers and weeds are likely to be infested by cabbage moth.

Description and Life History The adult moths are about 9 millimetres long and greyish brown. At rest, the ridge formed by the folded wings shows a row of diamond-shaped yellow markings. The hindwings are fringed with long grey hairs. The moths are active, and may fly out from the plants in swarms when the infestation is heavy.

Eggs are laid on the undersides of leaves. They hatch in a few days to slender colourless caterpillars that feed on the surface tissues of the leaves, and sometimes mine between the two surfaces of the leaf to leave small clear 'windows'. The caterpillars grow rapidly, become green, and perforate the outer leaves by chewing large pieces out of them. As the plants grow older, the caterpillars feed mainly on the more tender centre leaves. When disturbed they drop and hang by a silken thread. They feed for ten days to a month, and when full-fed are 12 millimetres long. Then the larvae spin flimsy, net-like cocoons and pupate inside them. These cocoons, with the brown pupae inside, are scattered

over the plant. The adult emerges after one or two weeks. The life cycle may be as short as sixteen days and there is a number of generations per year.

Cabbage moth usually overwinters as the adult, sheltering amongst the inner leaves of the plants, but in certain districts some feeding also occurs in winter.

Injury The larvae, if numerous, eat holes in leaves all over the plant, giving a lacy pattern. They penetrate the heart and produce a lot of webbing and excreta, thus ruining the plant.

Young cabbage moth caterpillars and damage to cabbage leaf.

Damage by cabbage moth.

Dispersal The moths are strong fliers.

Control measures

NATURAL Several imported wasp parasites – *Hymenobosmina rapi* (Cameron), *Horogenes cerophaga* Gravenhorst, *Thyraeella collaris* Gravenhorst and *Apanteles plutellae* Kurdjumov – are well-established (Wilson, 1960).

APPLIED Treatment as recommended opposite for the cabbage white butterfly controls this moth. It is equally important for this pest that the undersides of outside leaves be thoroughly treated.

Cluster caterpillar *Spodoptera litura*

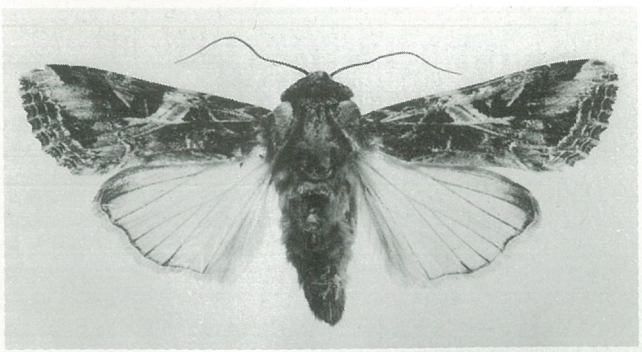
Importance and Distribution Infestation by this pest in late summer is reported in most seasons on cabbages and cauliflowers in the coastal districts. Usually it is confined to occasional plants, but in some seasons damage is considerable.

Conditions for Infestation Most trouble seems to occur in seasons when late summer rainfall is above average.

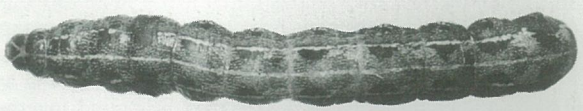
Plants attacked A wide range of plants is attacked by this species including tobacco, tomatoes, apples, cotton, many broad-leafed weeds, as well as cabbages and cauliflowers.

Description and Life History The adults are thick-set greyish brown moths of the cutworm type. The forewings, marbled with silvery lines, have a wingspan of 3 to 4.5 centimetres and the hindwings are silvery white and almost transparent.

Eggs are laid on the undersides of leaves, usually the outer lower leaves, in clusters and are covered with brownish short velvety scales from the moth's body. At first, the young larvae feed on the epidermis of the underside of the leaf, exposing the soft dark green tissue beneath; they feed in clusters. The affected area is easily distinguishable against the lighter greyish background of the leaf. Later the larvae feed singly and make big



Cluster caterpillar – adult. (Wingspan 3 to 4.5 cm)



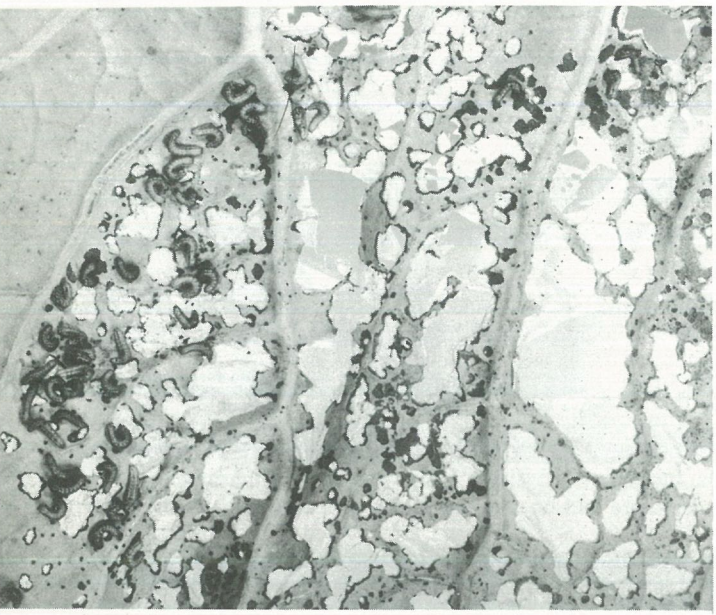
Cluster caterpillar – fully-developed larva. (Length 4 to 5 cm)

holes, and may penetrate the heart of a cabbage. The full-grown smooth grubs are 4 to 5 centimetres long, and vary from green to brownish purple with a row of dark triangular spots on each side of the body. They pupate in the soil. Unlike cutworms, these grubs feed during the day and do not leave the plant until they are ready to pupate.

Injury Large larvae damage foliage severely, and may penetrate the heart of a cabbage. It is not easy to distinguish the damage from that of other caterpillars, except from the feeding pattern of the young grubs.

Dispersal The moths are strong fliers.

Control measures See cabbage white butterfly on page 250.



Young cluster caterpillars and their damage.

Injury When young plants are attacked they usually wither and die. Older plants become stunted, and develop lateral buds to produce multiple heads of no commercial value.

Dispersal The adult moths are strong fliers.

Control measures Early attack by centre grub is often inconspicuous. The injury may be well advanced before it is seen and the plants may already be damaged beyond recovery. However, regular treatment for the cabbage white butterfly, starting with the seedbed, will avoid injury from this grub.

Cabbage-centre grub. (Length, when fully developed, about 12 mm)

Cabbage-centre grub *Hellula hydralis*

Importance and Distribution This pest is usually of only minor importance, but may occasionally do severe damage especially to rape, turnips and cabbages. It occurs in coastal and inland districts.

Conditions for Infestation Hot dry weather is favourable to the development of this pest. However, it is most likely to be troublesome in autumn, and may also occur in spring.

Plants attacked It has been observed on rape, turnips and cabbages.

Description and Life History The moths are about 12 millimetres long and hold their wings horizontally. The forewings are grey with brown markings. Eggs are laid on the younger parts of the plant, and the young larvae burrow into the centre of the growing point. The tunnels are sealed with webbing and frass, and some of the terminal leaves may be bound together. In older plants, the main veins may be tunnelled. When full-grown, the thick-set larvae are about 12 millimetres long and yellowish with brown stripes. They pupate in the tunnels.

Loopers *Chrysodeixis* spp.

In mild moist seasons when cloudy weather is frequent, damage by loopers is sometimes severe in late spring or early autumn. They are distinguished by their looping action. The larvae are green, except when they are very young and almost transparent. They feed on the backs of the leaves, eating holes that may be as much as 2.5 centimetres across.

Control measures Loopers are generally controlled by the measures adopted for cabbage white butterfly. If some should appear later in the life of the crop, they can be killed by applying a spray of mevinphos 0.07 per cent, which must be used with great care because of its high toxicity.

Loopers are discussed in greater detail on page 223 under Bean Pests.

Budworms *Heliothis* spp.

The caterpillars are sometimes pests of cabbages in coastal districts, chewing younger heart leaves in a ragged manner. They often bore directly into the centre of the heart. While this damage is not really common, it is difficult to deal with as the hearts are nearly mature. If control is necessary, spraying with mevinphos 0.07 per cent provides a satisfactory answer, but it must be used carefully because of its high toxicity.

These pests are discussed in greater detail on page 219 under Bean Pests.

Cutworms *Agrotis* spp.

Cabbages and cauliflowers planted out on land which has recently been either weed-infested or flooded are always in danger from cutworms. Young, newly-planted or recently-sown plants are nipped off during the night. After a few nights of such damage re-planting may become necessary.

Control measures Control is not difficult. Seedlings may be sprayed at ground level with endosulfan 0.07 per cent. Land which is thought to be infested by cutworms can be cleared of them by using lindane-bran bait.

Cutworms are discussed more fully on page 221 under Bean Pests.

DIPTERA

Onion maggot *Delia platura*

Young cruciferous plants are sometimes attacked soon after germination or transplantation by small white maggots that bore into the stems below ground and often hollow them out. The tops die and the stems, when pulled up, are found to be soft and rotted.

These maggots are the larvae of small grey flies. Infestation usually occurs when material such as blood and bone fertilizer or animal manure has been used on the land at, or shortly before, planting. The trouble is much more likely to occur on sandy soils than on other types.

Further details of this pest are given on page 228 under Bean Pests.

A leaf-miner Agromyzidae

Young cruciferous plants sometimes have pale lines on the leaves which, on examination, are seen to be caused by tiny maggots burrowing between the two surfaces. When the infestation is heavy the tunnels occupy so much of the leaf that it dies. The flies are grey, about 3 millimetres long, and lay their eggs in the leaf tissue. Full-grown maggots are about 5 millimetres long; they pupate inside the leaves. The species has not yet been determined. Kleinschmidt (1970) has recorded the introduced *Liriomyza brassicae* (Riley) as infesting crucifers in Queensland.

Plants growing in good conditions are generally not harmed significantly, but if their growth is checked, as by dry weather, the leaf mining may do some damage. Control measures recommended for cabbage white butterfly on page 250 will normally prevent infestation by this pest.

COLEOPTERA

Vegetable weevil *Listroderes obliquus*

Importance and Distribution The vegetable weevil is a native of Brazil which became established in New South Wales in the early part of this century. Both larvae and adults attack many vegetable crops, and can cause severe losses in winter and spring.

Conditions for Infestation These weevils seem to be equally at home in coastal districts and inland, and are especially abundant in the Murrumbidgee Irrigation Area. Wherever there is a heavy growth of capeweed, vegetable weevil must be expected.

Plants attacked This pest seems to be almost omnivorous. Cruciferous plants, especially cabbages and turnips, carrots, lettuce, silver beet and spinach, are amongst the vegetables most favoured by the larvae. Winter-growing flowers, such as stocks, cinerarias, Iceland poppies and pansies, and weeds, such as capeweed, marshmallow and cudweed, are heavily attacked. The adults also damage crucifers grown in the spring, but are most commonly seen attacking crops such as potatoes and tomatoes.

Description and Life History The inconspicuous adults are grey-brown, about 9 millimetres long, and often stained with soil. On the wing covers they have V-shaped markings made up of light grey scales.

They are rather box-shaped, and have a prominent snout. They emerge from pupae in late August and September, and feed on plants in October and November. They become inactive in the soil through the summer until late autumn when they lay eggs. At this time the adults may feed again to a limited extent. Eggs (several hundred per weevil) are rounded and green or yellow, and are laid in the soil or on plant stems. There are no males. All the weevils can lay fertile eggs.

The adult weevils feed at night and hide in the soil near the plant bases during the day. When disturbed, they drop from the plant and feign death, and are difficult to see.

The cream-coloured larvae are thick-set and curved. With age they become green or greenish yellow. They feed at night and during the day may shelter in the soil or, on occasions, in the growing point of a young plant. When full-grown they are 12 millimetres long and have a series of short dark dotted lines on the head. The larvae feed during winter and pupate in the early spring in earthen cells in the soil.

Vegetable weevil
Listroderes obliquus

1 Eggs; **2** larva; **3** pupa, in earthen cell; **4** adult weevil; all enlarged five times. **5** Earthen cell from which adult has emerged; **6** carrots damaged by larvae and adults; all actual size.

Injury The damage done by young grubs to small plants is not obvious at first, but the plants make no growth and inspection shows that the young centre leaves are fretted and perforated. The small larvae may sometimes be found hiding in the centre of the growing plant. In later stages, the larvae make ragged holes in the leaves. The injury by the adults in late spring can be spectacular as they swarm on the plants at night, devour the foliage and sometimes the stalks, or leave the stalks pitted with holes.

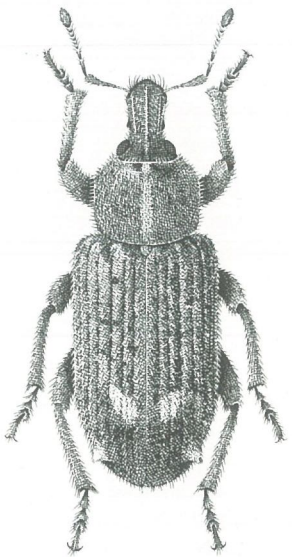
Dispersal The weevils do not fly. They crawl from a breeding source to the crop. Their more widespread distribution is aided by a number of characteristics. They are sturdy, inconspicuous and long-lived, and shelter in debris, boxes and other transportable objects. As they need no food when inactive, their survival rate after journeys can be high. They are parthenogenetic so only one individual can start a colony. Their wide range of host plants and tolerance of a wide climatic range make it possible for them to survive and multiply almost anywhere in the State.

Distribution is also common on seedlings, as the tiny grubs often shelter in young plants in the daytime.

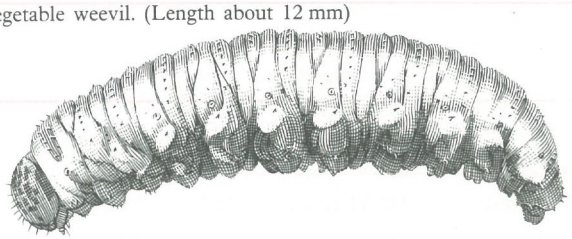
Control measures

NATURAL A tachinid fly and several wasp parasites, *Tersilochus* spp., were introduced by CSIRO, but successful establishment was not recorded (Wilson, 1960; Anon, 1965).

APPLIED Clean cultivation and the elimination of favoured weed hosts, such as capeweed and marshmallow, are important first steps. When weedy non-grazing areas adjoin land to be cropped, it could be worthwhile boom spraying the crop area with DDT or baiting it with a suitable bait. When the plants are known to be infested, spraying with DDT 0.1 per cent, aimed at both the plants and the soil beneath them, has been very effective. Another method is to use lindane-bran bait as described for cutworms on page 222 under Bean Pests.



Vegetable weevil. (Length about 12 mm)



Vegetable weevil larva. (Length about 12 mm)

White fringed weevil *Graphognathus leucoloma*

Cabbage and cauliflower plants are likely to be attacked by the larvae of this weevil when they are set out in land which has recently been under lucerne or clovers, or which has carried many broad-leafed weeds for some time. This type of attack is not uncommon on river-flat country. The plants wilt suddenly as the roots are channelled and girdled by the thick-set legless white or grey grubs, up to 12 millimetres long, which may be found in the soil nearby. Infestation is most likely in plants set out in December or January.

Adults emerge from the soil, usually in late summer. They may swarm to cruciferous crops from nearby breeding sources, such as lucerne or weeds. They can devour young crucifers. The slate grey adults are about 12 millimetres long with short broad snouts.

This pest is discussed in more detail on page 281 under Potato Pests.

A ground beetle *Clivina biplagiata*

This carabid beetle is related to beetles which feed mainly on other insects or insect remains. This species attacks plants occasionally. The beetles have been found doing considerable injury to newly-transplanted cauliflowers in the Bathurst district in mid-summer. They are dark brown, narrow and about 8 millimetres long. They scurry rapidly out of sight when disturbed, hiding under clods and stones. They chew the cauliflower stems close to ground level and the tap-roots.

Spotted vegetable weevil *Desiantha diversipes*

This brownish grey weevil is about 6 millimetres long. It sometimes damages turnips severely in tableland districts in autumn, by feeding on the leaves and stalks. The weevils may move in to the crop on a face from adjacent pasture, eating the turnip plants as they go.

African black beetle *Heteronychus arator*

Adult African black beetles sometimes attack young transplanted cabbage and cauliflower crops if these are planted on land recently under pasture, or where the beetles can move in from nearby pasture. Occasionally the beetles have been transported to crop land by flood waters. The pest is most common on river flats in coastal areas. The squat shining black beetles are about 12 millimetres long. They attack the plants just below ground level by chewing the stems, and leave them frayed out like teased rope.

Control measures When infested land is to be used, a lindane-broken maize bait should be applied before the vegetables are planted. The dead beetles will be lying on the ground a day later.

If the plants are already being damaged, jetting around the stems with DDT emulsion 0.1 per cent has proved to be effective. Once the cruciferous transplants are well established they are no longer in danger.

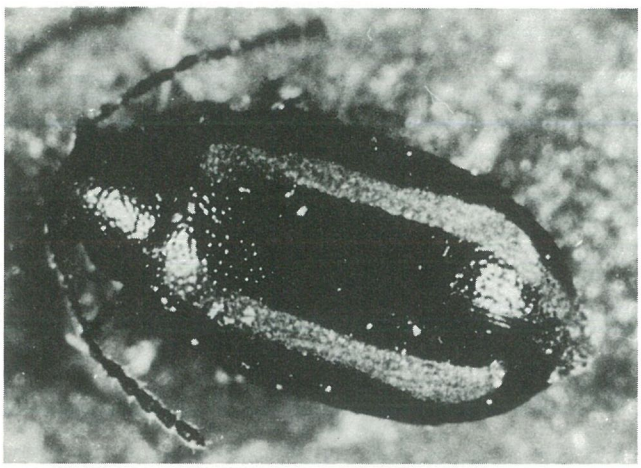
This pest is described in greater detail on page 295 under Tomato Pests.

Striped flea beetle *Phyllotreta nemorum*

This small beetle, which jumps or flies readily when disturbed, is an important pest of cruciferous plants in England, especially on turnips. It is now common in New South Wales. Damage from feeding on the foliage of turnips and cabbage is usually not great. Small holes are chewed in the leaves, giving the appearance of peppering by fine shot.

The adult beetle is about 2.5 millimetres long, and black with a longitudinal yellow stripe on each wing cover.

Control measures Control, where necessary, could be expected from a carbaryl 0.1 per cent spray.



Striped flea beetle. (Length about 2.5 mm)

Wireworms Elateridae
False wireworms Tenebrionidae

Cabbages and cauliflowers which are transplanted into ground recently under pasture may be attacked by wireworm and false wireworm larvae. They nibble at the roots and may tunnel in the stalks. This damage stunts the plants, or may even kill them. The wireworm and false wireworm larvae are sporadic winter and spring pests of several vegetables.

Wireworms, the larvae of 'click beetles', and false wireworm larvae are cylindrical or flattened, and brown and hard or cream and soft-bodied. They may be up to 3.5 centimetres long when fully developed.

Control measures Thorough preparation of the land many weeks before planting will reduce the wireworm and false wireworm populations. Jetting around the young plants with lindane 0.01 per cent has halted the damage by these pests.

THYSANOPTERA

Onion thrips *Thrips tabaci*

During dry weather, young cabbages and cauliflowers sometimes seem to be slow in growth. Examination of the undersides of the lower outer leaves shows them to be shiny and light brown, and reveals the small narrow brown or yellow thrips. They pierce the surface plant cells and suck up the juices. They attack many plant species, and are most abundant in dry seasons and on non-irrigated crops. A good fall of rain or irrigation usually ends the trouble without resort to chemical control.

Control measures On crucifers, spraying with dimethoate 0.03 per cent is recommended (undersides of leaves must be treated).

Further details of this insect and its control are given on page 272 under Onion Pests.

HEMIPTERA

Cabbage aphid *Brevicoryne brassicae*

Importance and Distribution This aphid occurs throughout the world, and can be a serious pest of crucifers wherever they are grown. In New South Wales, commercial crops grown during late summer or autumn may need to be treated if damage is to be avoided.

Conditions for Infestation Warm dry conditions suit the cabbage aphid, which is usually most abundant between February and May. In coastal districts the aphids are sometimes important in the spring also.

Plants attacked Crucifers of all sorts are likely to be attacked.

Description and Life History Cabbage aphids are globular and about 2.5 millimetres long when mature. They are slaty grey with a mealy covering or bloom. Globules of honeydew covered with the mealy substance may be seen amongst the aphid colonies. Wingless and winged forms occur together on the same plant.

Infestation usually starts on the upper surface of a leaf – a single winged female surrounded by wingless young. The leaves curl in and protect the colonies. Reproduction is rapid, but in Australia no eggs are laid. (In colder countries this species has an egg-laying form and the eggs overwinter.) Active young are born alive. In cooler areas the wingless forms overwinter and their young develop wings in the spring. In the warmer part of the year a generation matures in two weeks.

Injury Infested plants stop growing, and the leaves are distorted and mottled. If aphid numbers are very large, the plants become smothered with the insects, wilt suddenly and die. A lesser infestation can make the plant unfit for the market.

Cabbage infested by cabbage aphid.

Dispersal Winged forms are usually produced when the colony is crowded. The spread of the infestation through a crop is rapid.

Control measures

NATURAL Cabbage aphids are attacked by several enemies, the most useful being the common spotted ladybird, *Harmonia conformis*, and a wasp parasite, *Diaeretus rapae* (M'Intosh). This little wasp leaves many swollen empty aphid bodies on the plants, each with a small hole through which the adult wasp has emerged. While these enemies kill many aphids they do not usually exert much influence on the population until after a good deal of damage has been done to the crop.

APPLIED Control can be achieved by thorough spraying with demeton-S-methyl 0.025 per cent, or dimethoate 0.03 per cent, or maldison 0.075 per cent, or mevinphos 0.07 per cent. Maldison 5 per cent dust may also be used effectively. Because of its high toxicity, special care should be taken when applying mevinphos.

Nicotine sulphate and soap sprays or 5 per cent nicotine dust were used for many years against cabbage aphid.

Good crop hygiene, with prompt disposal of spent crops, and the siting of seedbeds away from obvious sources of infestation will also contribute to successful control.

Green peach aphid *Myzus persicae*

Cruciferous crops may occasionally be heavily infested by this species; the small green aphids cluster thickly on the undersides of leaves. This may happen in spring or autumn. At most times of year only wingless forms are present, but at other times winged aphids are produced.

Heavy infestations may cause cabbages and cauliflowers to wilt, but the damage is not nearly as severe as that of the cabbage aphid.

Control measures The cabbage aphid control recommendations are applicable to green peach aphid.

More information will be found on page 131 under Peach and Nectarine Pests and on page 298 under Tomato Pests.

Plant bugs of minor importance on cruciferous crops

RUTHERGLEN BUG, *Nysius vinitor* Both the immature and winged stages may sometimes invade the crops in swarms from nearby breeding sources, usually weed growth. In particular, they can be a serious factor in limiting the production of seed crops. They may cause severe wilting and the fouling of the plants with excreta. The adults are grey-brown and about 5 millimetres long.

They are described more fully on page 163 under Grape Pests.

GREEN VEGETABLE BUG, *Nezara viridula* Adults that have bred on other plants and migrated to the cabbages sometimes heavily infest hearting cabbage crops in autumn. The sucking of sap causes the heart foliage to turn pale, soft and spongy, and later brown. As the cabbages will be almost ready for harvest, any insecticide used should have a short residual life.

Details of life history and control are given on page 232 under Bean Pests.

HARLEQUIN BUG, *Dindymus versicolor* These bugs sometimes attack cabbages as well as other vegetables. They are particoloured insects with orange, black, yellow and green patches, and are about 12 millimetres long.

Control measures recommended for the green vegetable bug on page 233 under Bean Pests are effective against these bugs.

ORTHOPTERA

Black field cricket *Teleogryllus commodus*

Importance and Distribution Black field crickets may cause damage in many parts of New South Wales, especially on river-flat country and in irrigation areas. They sometimes attack swedes, turnips and other crucifers, as well as many other crops. Occasionally, they are a domestic nuisance when they swarm to lights and into houses, where they have been known to damage clothing and other fabrics.

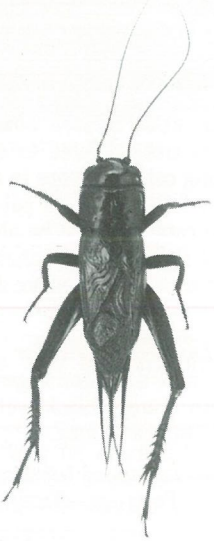
Conditions for Infestation Clay soils which crack on drying are favoured. Wet seasons suit crickets and so do conditions following river floods.

Plants attacked Young plants of all sorts may be attacked, including young trees. Most damage is in the autumn, but it may occur as early as the end of spring.

Description and Life History The adults are about 2.5 centimetres long and black or dark brown. They have two pairs of wings and are strong fliers. The hindwings are gauzy and are folded beneath the shorter horny forewings. The hind legs are stronger than the other legs, and are adapted for jumping. The males produce a chirping sound by moving their wings. The female has a long ovipositor with which she places eggs in cracks in the soil.

Adults are active in summer and autumn and deposit eggs after the first autumn rains. Feeding, mating and egg-laying take place in the late afternoon, while for most of the day the insects hide in soil cracks and under trash. Within a month or so of egg-laying, the adult crickets die.

The banana-shaped eggs are cream, and a female may lay 300. The eggs develop slowly, if at all, in the winter and hatch late in the following spring (Hogan, 1966). The nymphs resemble the adults except they have no wings. There is only one generation a year.



Black field cricket. (Length about 2.5 cm)

Injury Nymphs or adults can eat the central part of young cruciferous crops and may graze them right to the ground, though the attack is often not so severe.

Dispersal The adults are strong fliers. Nymphs can crawl and hop actively, and may cover considerable distances.

Control measures

NATURAL Black field crickets seem to be rather free from natural enemies. However, in Victoria a wasp parasite of the eggs, *Procacus dubius* (Nixon), has been recorded parasitizing a high proportion of the cricket eggs (Anon, 1960).

APPLIED A maldison-wheat bait (180 grams maldison in 17 kilograms wheat per hectare) broadcast in the late afternoon is recommended.

Wingless grasshopper *Phaulacridium vittatum*

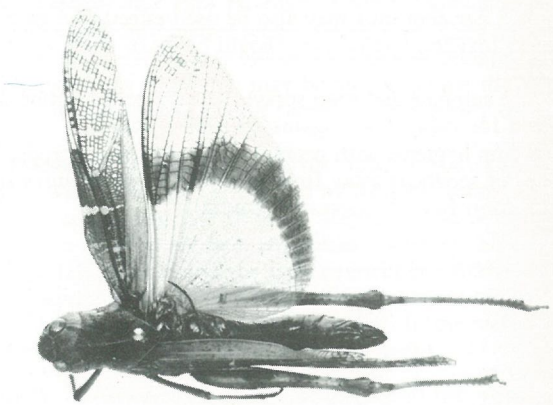
This pest of the tablelands area is discussed on page 111 under Apple Pests and on page 275 under Pea Pests.

Wingless grasshopper damage.

Yellow-winged locust *Gastrimargus musicus*

These large locusts, up to 5 centimetres long, sometimes attack cruciferous crops on the tablelands and slopes in summer, and reduce the plants to leafless stalks. The hindwings are bright yellow, and they make a clicking sound in flight. They can do a great deal of damage in a short time.

Control measures Control is difficult as the winged insects may continue to invade in moderate numbers. Control measures recommended for wingless grasshopper on page 112 should kill them.



Yellow-winged locust. (Length up to 5 cm)

ARACHNIDA ACARINA

Red-legged earth mite *Halotydeus destructor*
Blue oat mite *Penthaleus major*

During autumn, winter and spring in inland districts these earth mites may infest cruciferous crops, and can seriously damage young plants. They suck the juices from the upper surfaces of leaves, thus producing silvery or whitish blemishes, particularly along the main veins. When the infestation is heavy, whole leaves may look bleached. The damage is often wrongly attributed to frost. The mites feed at night, or by day in cloudy weather.

Further details of these mites will be found on page 275 under Pea Pests.

Cucurbit pests

Cucurbits include pumpkin, melon, cucumber, marrow, squash, choko and gherkin. They are grown in most parts of New South Wales in frost-free situations with abundant rainfall or with irrigation. They are warm-weather crops and all are sown, grown and harvested during spring, summer and autumn.

The earliest crops mature in the spring on the Far North Coast. Large quantities of cucurbits are grown in the Murrumbidgee Irrigation Area and Murray, Hunter and Hawkesbury Valleys, and on the river flats of inland rivers.

A number of insect and mite pests may do damage wherever cucurbits are grown. Several are found only on the coast or only inland. Some are confined to cucurbits, but most are also pests of other crops. None of these pests requires routine treatments; control measures are begun only when the pest becomes obvious.

An account is given on pages 260 to 266 of the pests of cucurbit crops listed below.

ARTHROPODA
INSECTA

LEPIDOPTERA

Cucumber moth	*Phakellura indica* (Saunders)
Cutworms	*Agrotis* spp.

DIPTERA

Cucumber fly	*Dacus cucumis* French
Seedling bean midge	*Smittia macleayi* (Skuse)
Onion maggot	*Delia platura* (Meigen)

COLEOPTERA

Pumpkin beetle	*Aulacophora hilaris* (Boisduval)
Twenty-eight-spotted ladybird	*Henosepilachna vigintioctopunctata* (Fabricius)
Twenty-six-spotted ladybird	*Henosepilachna sparsa vigintisexpunctata* (Boisduval)
White fringed weevil	*Graphognathus leucoloma* (Boheman)
Fuller's rose weevil	*Asynonychus cervinus* (Boheman)
Monolepta beetle	*Monolepta australis* (Jacoby)

THYSANOPTERA

Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

Melon aphid	*Aphis gossypii* Glover
Cowpea aphid	*Aphis craccivora* Koch
Green vegetable bug	*Nezara viridula* Linnaeus
Green mirid	*Creontiades dilutus* (Stål)
Rutherglen bug	*Nysius vinitor* Bergroth
Greenhouse whitefly	*Trialeurodes vaporariorum* (Westwood)

ARACHNIDA ACARINA

Spider mites	*Tetranychus* spp.
Clover mite	*Bryobia cristata* (Dugès)
Red-legged earth mite	*Halotydeus destructor* (Tucker)
Blue oat mite	*Penthaleus major* (Dugès)
Broad mite	*Polyphagotarsonemus latus* (Banks)

INSECTA LEPIDOPTERA

Cucumber moth *Phakellura indica*

Importance and Distribution This pest occurs only occasionally in New South Wales in north-western areas in autumn, and has been recorded damaging cucumbers in autumn at Moree. In Queensland it commonly attacks watermelons, but cucumbers only occasionally. It occurs in Asia and Africa, and is listed in some countries as a pest of cotton.

Conditions for Infestation It is a warm-climate insect which is unlikely to cause trouble outside its present range in New South Wales. In Queensland, it is reported that attacks are most common after heavy rain (Anon, 1951).

Plants attacked This moth has been recorded on many different cucurbits in Queensland.

Description and Life History The adult is about 2.5 centimetres across the outspread wings which are translucent-white, with a broad dark brown edging that makes a continuous band along the front and sides of the forewing and the sides of the hindwing. The abdomen has a brush of long yellow scales at the tip.

Small round eggs are laid on the undersurfaces of leaves. The caterpillars are white when small, but become yellow-green and reach a length of 2.5 centimetres. They mature after about four weeks and pupate in light silken cocoons which are spun inside webbed leaves or leaf fragments. The moth emerges about a week later.

Injury At first the young larvae graze the undersurfaces of leaves. Later they eat large gaps in the foliage, and the ragged leaves may be bound together with silk. In severe cases the leaves are destroyed, and the larvae may burrow in the stems and gouge irregular-shaped holes in the fruit.

Dispersal No method of dispersal has been observed other than moth flight.

Control measures In Queensland, spraying with endosulfan 0.07 per cent is recommended.

Cutworms *Agrotis* spp.

Much damage can be done to young plants in only a few nights when cucurbits have been planted in ground infested by cutworms. These insects are likely to be in the soil if there has been recent flooding of the area or heavy weed growth. Young plants are killed by being cut off at ground level in the night. In the soil around the bases of the plants may be found the dark, turgid, smooth grubs that curl up in a circle when exposed.

Further details of cutworms and their control are discussed on page 221 under Bean Pests.

DIPTERA

Cucumber fly *Dacus cucumis*

Importance and Distribution This insect occurs commonly in Queensland coastal and sub-coastal districts (May, 1963), and attacks nearly all cucurbits. It is present on the Far North Coast of New South Wales, but is not important.

Conditions for Infestation It is a subtropical pest.

Plants attacked In Queensland it attacks cucurbits; tomatoes and ripe papaws (Anon, 1951).

Description and Life History The life history is similar to that of the Queensland fruit fly. The eggs are laid beneath the rind, and the cream-coloured maggots tunnel in the fruit. The larvae mature in about a week and then burrow in the soil to pupate. The whole life cycle can be completed in two weeks so populations can increase very rapidly. The adults are generally similar to Queensland fruit fly in appearance, but have a yellow median stripe on the upper surface of the thorax.

Injury The flies become numerous after mid-summer and lay their eggs in mature, damaged or sunburned fruits. When the flies are very abundant they attack immature fruits in which the eggs usually fail to hatch. Such unsuccessful punctures may show up later as calloused deformities on the fruit.

Dispersal The flies disperse readily by flight.

Control measures The elimination of breeding sources – damaged or over-ripe fruit – and spraying with dimethoate 0.03 per cent are recommended in Queensland.

Seedling bean midge *Smittia macleayi*

Cucumbers and marrows, planted early in the spring in land where soil temperatures have not reached a high enough level for rapid germination, are likely to be attacked by the larvae of this pest. The tiny white worm-like maggots enter the seeds through the bursting seed coat and feed on the inside surfaces of the cotyledons and on the growing point. When the seedlings emerge above ground they may be only blind stalks with one or both seed leaves missing. If the growing point has been damaged, but not destroyed, the plant will still be badly stunted.

The solution to the problem is to delay the sowing of such land until conditions are warm enough for the crop.

The seedling bean midge is discussed in more detail on page 228 under Bean Pests.

Onion maggot *Delia platura*

Injuries to cucurbits from the attacks of these maggots have been seen in coastal districts where they have been sown in land where the soil has recently been treated with large quantities of organic material. This material may have been a green manure crop, animal manure or blood and bone. The damaged seedlings usually wilt quickly and die soon after appearing above ground. The stem underground will have been hollowed out by the small white maggots, and it will usually have rotted.

Trouble from the pest may be avoided if the land is not planted soon after the treatment described above.

The onion maggot is described more fully on page 228 under Bean Pests.

COLEOPTERA

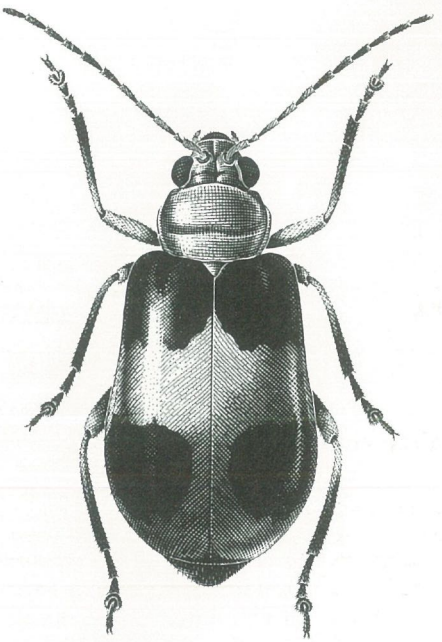
Pumpkin beetle *Aulacophora hilaris*

Importance and Distribution This pest attacks cucurbits, and under exceptional circumstances figs and cherries, throughout New South Wales, but it is most prevalent in the inland areas. It can kill young plants and cause severe losses.

Conditions for Infestation Warm dry conditions suit the pumpkin beetle so it is likely to be present every year inland, and in dry seasons on the coast.

Plants attacked All commercial cucurbit crops are attacked, as well as the wild melons which are probably the natural hosts of pumpkin beetle. Sometimes localized losses of figs and cherries have been due to these beetles.

Description and Life History The adults are about 6 millimetres long, and bright yellow with four black patches – one on each corner of the wing covers. They are unusually long-lived, having been known to live for ten months as adults. They overwinter as adults, often under loose bark where they have congregated in small groups. In spring they fly to seek host plants. They lay eggs in small clusters on dead leaves or moist soil under the plants. Egg-laying may go on for several months, with a female producing as many as 500 eggs. The eggs hatch in about ten days and the larvae feed on the roots or lower parts of stems. They may also feed on the surface of fruits lying on the ground. The cream-coloured larvae are full-fed in about five weeks when they are about 12 millimetres long. They pupate in the soil.



Pumpkin beetle. (Length about 6 mm)

Injury The adult beetles do the damage. The feeding of the larvae has not been proved to interfere with crops. The adults fly to the plants, and in a short time can kill cucurbit seedlings. They have the habit of clustering to feed on young leaves, tendrils and flowers and on young fruits. This clustering habit, however, does allow some seedlings on a hill to escape, or even branches of a plant that has been only partly attacked. Heavy attack results in serious injury. Flowers are destroyed and feeding on the skin of fruits produces disfiguring blemishes. Beetles are most abundant and harmful on warm calm days following wet or windy weather. They can cause severe damage to seedlings in the spring, not only directly but also by delaying crop maturity and marketing. They are most numerous and troublesome from November to March.

Dispersal Pumpkin beetles are strong fliers. In hot weather they are quite active and take wing quickly when disturbed.

Control measures

NATURAL Nothing is known of natural enemies.

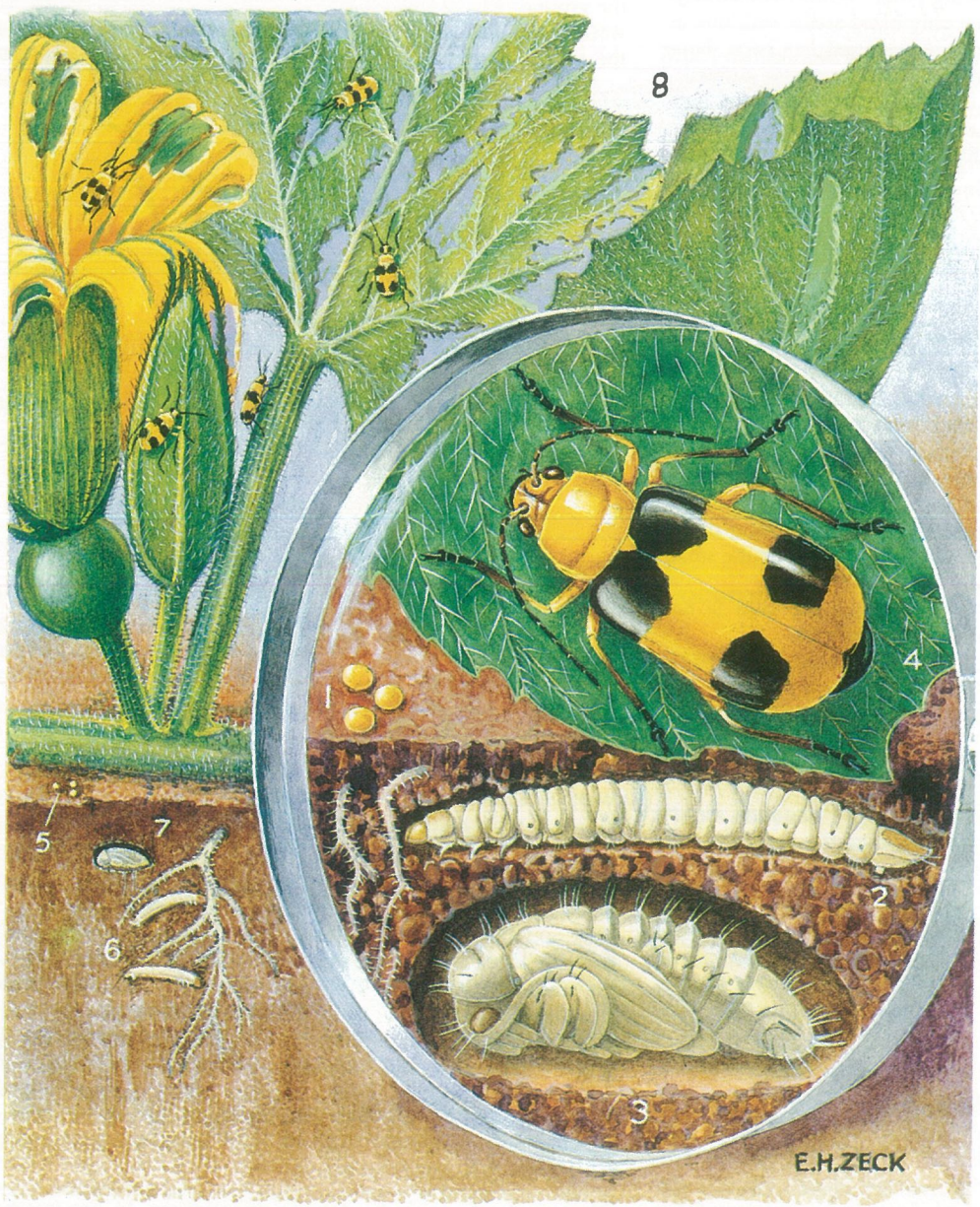
APPLIED It is important to protect young cucurbit plants from infestation by the beetles. It is customary to plant extra seed in each hill so that some seedlings may escape attack. For the first three weeks the plants can be protected by dusting with materials such as flour or hydrated lime. This has to be done daily for complete protection. Maldison dust 5 per cent is also effective.

After about three weeks the plants begin to grow vigorously and frequent attention is usually no longer needed. If the beetles continue to be numerous, maldison 5 per cent dust or carbaryl 0.1 per cent spray should be used.

Twenty-eight-spotted ladybird *Henosepilachna vigintioctopunctata*

Twenty-six-spotted ladybird *Henosepilachna sparsa vigintisexpunctata*

Importance and Distribution Leaf-eating ladybirds are common pests of cucurbits in New South Wales, especially in coastal districts, but also inland. When populations are heavy they spill over to crops other than cucurbits. *Henosepilachna sparsa vigintisexpunctata* is primarily a pest of potatoes and other solanaceous plants, but the two beetles probably occur together.



Pumpkin beetle
Aulacophora hilaris

1 Eggs on soil; enlarged eight times. **2** Larva in soil; enlarged six times. **3** Pupa in soil; **4** adult beetle; both enlarged eight times. **5** Eggs; **6** larva; **7** pupa; **8** pumpkin plant showing leaf and flower damage by beetles; all actual size.

Conditions for Infestation These beetles require higher humidity than the pumpkin beetle and thrive better on the coast than inland, but are damaging pests of cucurbits in the Murrumbidgee Irrigation Area.

Plants attacked All cucurbits may be attacked, but rockmelons are preferred. Because of the similarity of these *Henosepilachna* species, there is some doubt about the validity of records of attack by each of the leaf-eating ladybirds on a variety of crops.

Description and Life History The beetles are oval in shape, strongly convex in outline and about 6 millimetres long. They are mainly yellow-orange, with *H. sparsa vigintisexpunctata* displaying 26 black spots and *H. vigintioctopunctata* 28 black spots. The beetles can fly well, but they are somewhat sluggish and do not fly readily. Eggs are laid in clusters, generally on the undersurfaces of leaves. The larvae hatch in about a week, and can be full-fed in a further three weeks. At that stage they are 6 millimetres long, yellowish green, and covered with branched spines that give them a very 'burry' appearance. They pupate on the plant or on nearby trash, the pupa being stuck to the surface at its hind end. The life cycle occupies five or six weeks and all stages may be found on the plant at once.

Injury The adults feed on the upper surfaces of the leaves,

A leaf-eating ladybird
Henosepilachna vigintioctopunctata

1 Eggs; **2** larva; **3** pupa; all enlarged seven times. **4** Larva; **5** pupae attached to leaf; **6** adult ladybirds; **7** group of eggs; all actual size. **8** Adult ladybird; enlarged seven times.

often starting at the margin. The whole leaf may become light brown and papery where the top surface and all the body of the leaf has been eaten away. Sometimes the adults eat holes right through, leaving only veins. The larvae feed in the same way but generally on the undersurface. Sometimes young fruits have part of their skin eaten which results in an unsightly blemish.

Beetles are active from about October to April, less so in late autumn, and quiescent but alive during winter.

Dispersal Movement between plants and fields is primarily by flight of the adults.

Control measures Carbaryl spray 0.1 per cent or maldison dust 5 per cent is recommended.

Leaf-eating ladybirds and larvae. (Length of adult about 6 mm)

White fringed weevil *Graphognathus leucoloma*

Cucurbits, sown on land which has recently been under lucerne or clover, are sometimes attacked by the larvae of this pest remaining from the previous host plants. They attack the main roots and underground stem which may be ringbarked or extensively furrowed. The plants become stunted, and some may die. Examination shows the creamy thick-set legless grubs on the roots and in the soil beside them. The adult is a slaty grey weevil 12 millimetres long.

The white fringed weevil is described in more detail on page 281 under Potato Pests.

Fuller's rose weevil *Asynonychus cervinus*

Cucurbit plants, sown in early spring in the Central Coast district of New South Wales, may be attacked by the larvae of this beetle if the ground was under a heavy growth of weeds such as Paddy's lucerne during the previous summer, autumn or winter. The attacked plants show slow growth. The roots and stem underground are gouged or pitted by the small white legless grubs.

This insect is more fully discussed on page 36 under Citrus Pests and page 229 under Bean Pests.

Monolepta beetle *Monolepta australis*

This native insect is about 6 millimetres long, and yellow with red bases to the wing covers. It has the habit of appearing in swarms without warning and eating a great variety of plants, particularly the foliage, flowers and young fruit. The swarms tend to stay together. The beetles may nearly strip one plant and leave another similar plant untouched. The pest is well-known on the North Coast of New South Wales. Its life history and the situation in which the larvae occur are not known. Swarms may appear at any time but are more likely in spring or summer than in cooler weather.

Injury Plants that have been attacked look as if they have been scorched by fire due to the perforation of foliage by the beetles. A lesser degree of infestation may interfere with fruit setting.

Control measures Each swarm can be controlled individually by spraying with carbaryl 0.1 per cent.

THYSANOPTERA

Onion thrips *Thrips tabaci*

Young cucurbit plants in coastal districts of New South Wales often suffer attack by these thrips in dry weather. Plant growth is slowed. The undersides of leaves become bronze or dull silver in appearance and rather shiny. The leaf margins turn down and there is some mottling.

Control measures On cucurbits, spraying with dimethoate 0.03 per cent, or maldison 0.06 per cent is recommended when the damage first appears.

Onion thrips is more fully described on page 272 under Onion Pests.

HEMIPTERA

Melon aphid *Aphis gossypii*

Importance and Distribution This insect, which is also known as 'cotton aphid', may be found almost anywhere in New South Wales attacking many different plants.

Conditions for Infestation Melon aphid is usually more abundant in spring and autumn.

Plants attacked Most cucurbits are attacked but this aphid prefers melons, pumpkins and cucumbers. Cotton and many ornamentals are also acceptable hosts.

Description and Life History This species varies in colour from yellow to dark green and almost black, with the darker forms being dominant on cucurbits. It often carries a mealy or waxy bloom. Winged and wingless forms occur together. Reproduction is rapid and colonies build up in a few days. They may start on the undersides of leaves, but soon all parts of the plants may be infested.

Injury Leaves may wither, exposing fruits to sunburn. Much honeydew is produced which makes fruit unsightly.

Dispersal Migratory winged adults are produced by the colonies under the stimulus of crowding, and these disperse.

Control measures

NATURAL The many natural enemies – ladybird beetles, particularly the common ladybird, *Harmonia conformis*, lacewing larvae and wasp parasites – probably prevent aphid populations from becoming very numerous.

APPLIED Spraying with demeton-S-methyl 0.025 per cent, or dimethoate 0.03 per cent, or maldison 0.06 per cent is recommended.

Cowpea aphid *Aphis craccivora*

During September and October young cucurbit plants in coastal districts of New South Wales may suddenly become infested by winged greenish black aphids that are wind-borne from their breeding situations on inland pastures. On the crop they breed rapidly, and harm the central growing points and young leaves, thus stunting growth.

More detail and methods of control are given on page 234 under Bean Pests.

Green vegetable bug *Nezara viridula*

Attack on cucurbits usually results in pale dry patches on the fruit. Damage to the stalks sometimes prevents the proper maturation of the fruits.

This insect is more fully described on page 232 under Bean Pests.

Green mirid *Creontiades dilutus*

Cucurbit plants in coastal districts are sometimes attacked during the spring by pale green, narrow, active bugs about 6 millimetres long. They suck the juices from the growing points of young plants and the points turn yellow and drop out. On cucurbits, this bug has not been very destructive, but it probably delays the growth of some early crops.

Further information on green mirid is given on page 231 under Bean Pests.

Rutherglen bug *Nysius vinitor*

Cucurbits are occasionally the subject of Rutherglen bug attack, and may be killed by this native pest. Sometimes swarms of the winged forms are responsible, but it is not uncommon to see hordes of the young wingless bugs, perhaps with a few adults, crawling into the crop from nearby weedy areas where they have bred.

Rutherglen bug is discussed in more detail on page 163 under Grape Pests.

Greenhouse whitefly *Trialeurodes vaporariorum*

Cucurbits, especially cucumbers, if grown in humid protected places are sometimes infested by these small, white-winged, moth-like insects. Gross attack will result in some wilting and an excessive contamination of fruit by sooty mould.

Further information is given on page 235 under Bean Pests.

ARACHNIDA ACARINA

Spider mites *Tetranychus* spp.

Spider mites are common pests of cucurbits especially in dry seasons. All varieties may be infested, but it is only in cucumbers, and perhaps rockmelons, that severe injury follows. Frequently, trouble results from sowing in land that previously carried a crop or weeds which were heavily infested.

Infested leaves take on a greyish stippled appearance, then turn yellowish before becoming brown and withered. Fine grey webbing may be seen on the undersurfaces of leaves.

Control measures Infestation is best avoided by care in the selection and preparation of a site for the crop, and by not introducing mites from infested areas nearby. When the mites

appear, applying sulphur dust will control them if it is done thoroughly and is repeated in a week to catch the young mites hatching from eggs. Sulphur can burn plants in very hot weather. The object should be to spread a fine film of dust on the undersides of the leaves. Other measures mentioned for control on page 238 under Bean Pests may be used.

Further description will be found on page 236 under Bean Pests.

Clover mite *Bryobia cristata*

Young cucurbit plants are sometimes injured slightly by colonies of migrating clover mites. The tiny brownish mites have long front legs, feed at night, and rest on the plants during the day. Finely-peppered greyish spots appear on the leaves. Should control be necessary, any of the methods recommended above for spider mites would be effective.

Red-legged earth mite *Halotydeus destructor*
Blue oat mite *Penthaleus major*

In inland areas, early-sown cucurbits sometimes suffer severely from attack by these mites. They suck the juices from the upper surfaces of leaves, thus producing silvery or whitish blemishes, particularly along the main veins. When the infestation is heavy, whole leaves may look bleached. The damage is often wrongly attributed to frost. The mites feed at night, or by day in cloudy weather.

More details and control measures are given on page 275 under Pea Pests.

Broad mite *Polyphagotarsonemus latus*

In coastal districts during summer, under very humid conditions vigorously-growing cucumbers and chokos sometimes take on a peculiar appearance – the young leaves become narrow and strap-like, and mottled with a pronounced down-curling of the margins. The damage is similar to that caused by 2,4-D weedicide, but the condition is known to result from the attacks of tiny whitish or glassy-looking mites which are visible when the leaf is unrolled. The mites move quickly.

Control measures Sulphur dust or dispersible sulphur spray will readily control these pests, but repeated applications may be necessary.

Further details will be found on page 79 under Citrus Pests.

Lettuce pests

Lettuce is in demand throughout the year so growers make successive sowings to provide a regular supply for the market. Much of the commercial production is carried out in market gardens near big towns and cities, and in inland irrigation areas. The crop can be sown throughout the year on the coast, from August to early March on the tablelands, and from March to August further inland.

At times lettuce is subject to attack by many of the pests of other vegetables. As it is a short term crop, care must be taken to minimize pest-caused setbacks to plant vigour.

An account is given on pages 267 to 270 of the pests of lettuce listed at right.

ARTHROPODA

INSECTA	LEPIDOPTERA
Budworms	*Heliothis* spp.
Cutworms	*Agrotis* spp.
Cluster caterpillar	*Spodoptera litura* (Fabricius)
Loopers	*Chrysodeixis* spp.
	DIPTERA
Cineraria leaf-miner	*Phytomyza syngenesiae* (Hardy)
	COLEOPTERA
Vegetable weevil	*Listroderes obliquus* Klug
White fringed weevil	*Graphognathus leucoloma* (Boheman)
Flea beetles	Halticinae
Monolepta beetle	*Monolepta australis* (Jacoby)

THYSANOPTERA

Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

Green vegetable bug	*Nezara viridula* (Linnaeus)
Rutherglen bug	*Nysius vinitor* Bergroth
Potato aphid	*Macrosiphum euphorbiae* (Thomas)

ORTHOPTERA

Wingless grasshopper	*Phaulacridium vittatum* (Sjöstedt)

DERMAPTERA

European earwig	*Forficula auricularia* Linnaeus

ARACHNIDA ACARINA

Red-legged earth mite	*Halotydeus destructor* (Tucker)
Blue oat mite	*Penthaleus major* (Dugès)
Spider mites	*Tetranychus* spp.

MOLLUSCA

GASTROPODA SIGMURETHRA

Common garden snail	*Helix aspersa* (Müller)
Reticulated slug	*Deroceras reticulatum* (Müller)
Brown slug	*Deroceras caruanae* (Pollonera)
Black-keeled slug	*Milax gagates* (Draparnaud)

ARTHROPODA

INSECTA LEPIDOPTERA

Budworms *Heliothis* spp.

A rather unusual type of attack on hearting lettuce is sometimes seen in spring and summer when these caterpillars feed avidly on the foliage and then bore directly into the heart. They may be up to 4 centimetres long, and are grey-green in colour with variable markings.

Control measures Control is difficult and the damaged plant is often not worth saving when the infestation is detected. If the grubs are seen when they are young, they may be killed with mevinphos 0.07 per cent spray, but this gives no residual protection and has to be used with great care because of its high toxicity.

See also page 219 under Bean Pests.

Cutworms *Agrotis* spp.

Lettuce plants are very susceptible to attack, especially when the land in which they are grown has recently been infested by weeds. Young plants are nipped off during the night and remnants of chewed leaf may be found on the soil surface.

Cutworms can be readily controlled by baiting or spraying as described on page 221 under Bean Pests.

Cluster caterpillar *Spodoptera litura*

Well-developed lettuce plants are sometimes attacked in late summer or early autumn by clusters of small grubs that feed in patches on the leaves. Later they feed singly and eat large holes.

Control measures Should control be needed on lettuce, spraying with mevinphos 0.07 per cent is recommended, but great care must be taken in handling this highly toxic insecticide.

Cluster caterpillars are discussed in more detail on page 251 under Cruciferous Pests.

Loopers *Chrysodeixis* spp.

These slender pale green caterpillars feed on the undersides of leaves and chew large holes. They are often difficult to see because of their protective coloration, especially when young. They are likely to be abundant in spring and in late summer, and are discussed in more detail on page 223 under Bean Pests.

DIPTERA

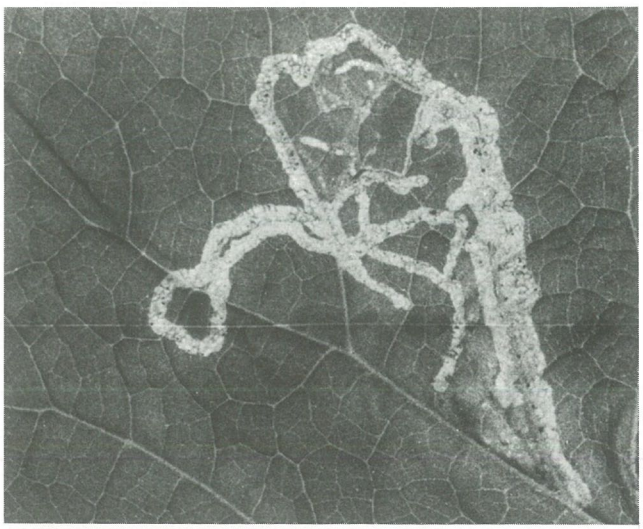
Cineraria leaf-miner *Phytomyza syngenesiae*

Importance and Distribution Lettuce plants are sometimes infested in winter and early spring by the leaf-mining maggot of this small fly. Its presence is indicated by thin thread-like mines in the leaves, which may gradually wither and die from the attack.

Plants attacked Cinerarias are the favourite host, but sow thistle, capeweed, prickly lettuce and some other plants are attacked as well as lettuce.

Description and Life History The adult fly is grey and 3 millimetres long. The females lay eggs within the leaf tissue, and the puncture marks or 'stings' may be seen as small scars. The maggots hatch in four or five days and eat the leaf cells between the upper and lower surfaces. As they move they leave thin pale mines; as they grow the mines widen to 1.5 millimetres. The full-fed larva is about 5 millimetres long. It forms a brown barrel-shaped pupa while still between the leaf skins, and the adult emerges ten days later. The life cycle is completed in three or four weeks.

Control measures Spraying with dimethoate 0.03 per cent should be effective. It is important, however, to begin spraying at the first sign of infestation, repeating the treatment at weekly intervals until the lettuces approach maturity if the flies are still active.

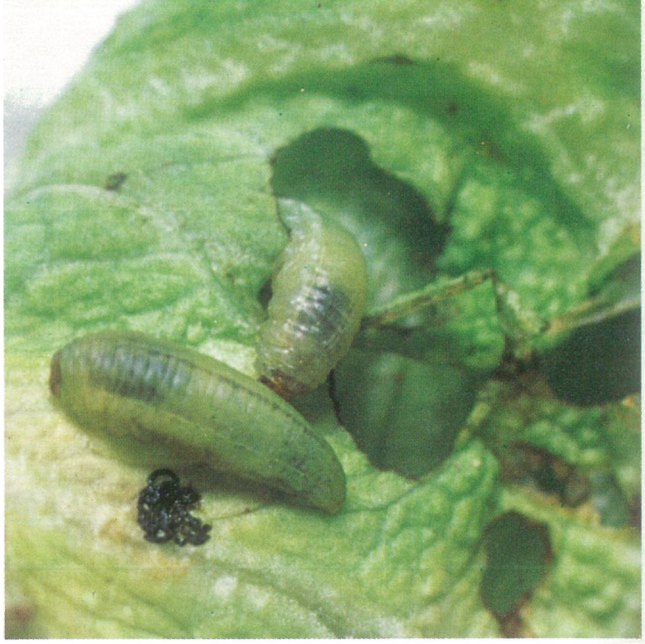


Cineraria leaf-miner damage.

COLEOPTERA

Vegetable weevil *Listroderes obliquus*

Lettuce sown or set out in late autumn, winter or early spring may be attacked by the larvae which are always likely to be active in land that has recently grown weeds. The small cream or pale green grubs, which are up to 12 millimetres long, feed on the centres of the plants and chew small holes in the leaves. Later in the spring the grey-brown weevils may attack, and in a few nights can destroy much of the crop by extensive ragged chewing of the foliage. The adults are about 12 millimetres long. They have a V-shaped mark on each wing cover.



Vegetable weevil larvae damaging lettuce. (Length of larvae, when fully developed, up to 12 mm)

Control measures It is most important to see that the land to be used for cool-season crops like lettuce is thoroughly fallowed and cultivated before sowing the crop. Where land is suspected of harbouring vegetable weevils, or when the crop is attacked, spraying with DDT 0.1 per cent or baiting with lindane-bran mixture has been successful in controlling them.

Further details on vegetable weevil are given on page 253 under Cruciferous Pests.

White fringed weevil *Graphognathus leucoloma*

Lettuce planted in land that has been under lucerne or clovers will sometimes wilt suddenly. When examined, it will be found to have had the roots nipped off, or channelled, by grey-white legless grubs which are the larvae of the white fringed weevil. The damage usually occurs in late spring when the grubs are nearly full-grown. Nothing can be done at this stage, but care should be taken when clover or lucerne pasture land is to be used for vegetables to give it a long weed-free fallow or, better still, grow a winter cereal crop on the land before planting the vegetables.

More details are given on page 281 under Potato Pests.

Flea beetles Halticinae

During spring lettuce may be attacked by small, usually dark, metallic beetles that hop when disturbed. Their feeding makes the lettuce look as if it had been peppered by fine shot.

Control measures suggested on page 284 under Potato Pests would also be suitable for lettuce.

Monolepta beetle *Monolepta australis*

North Coast lettuce crops are sometimes invaded by swarms of these small yellow and red beetles which nibble the leaves. On lettuce, spraying with carbaryl 0.1 per cent is suggested, but several applications will be needed if repeated invasions occur.

Further details on monolepta beetle will be found on page 264 under Cucurbit Pests.

THYSANOPTERA

Onion thrips *Thrips tabaci*

In dry spring weather these thrips sometimes stunt lettuce plants by feeding on the undersides of leaves. Damage is most likely to be severe on dryland crops. When the undersurfaces of leaves have been fed on they become shiny and have a dull leaden appearance. The tiny brown thrips can be seen on the injured area. Onion thrips is a vector of the spotted wilt virus which can be a serious disease in lettuce.

Control measures Dimethoate 0.03 per cent or maldison 0.06 per cent spray is recommended for control.

This insect is described more fully on page 272 under Onion Pests.

HEMIPTERA

Green vegetable bug *Nezara viridula*
Rutherglen bug *Nysius vinitor*

These bugs are sometimes troublesome on hearting plants and on seed-crop lettuce. For control, maldison 0.075 per cent spray or mevinphos 0.07 per cent spray has been found to be effective. Special precautions must be observed when using mevinphos because of its high toxicity.

These insects have been described on page 232 under Bean Pests and on page 163 under Grape Pests.

Potato aphid *Macrosiphum euphorbiae*

These green aphids often cause considerable injury to hearting lettuce in cool dry weather in autumn, winter or early spring. They can cluster thickly on the plant, causing wilting and producing copious sticky honeydew. The living and dead aphids spoil the market appeal of the produce.

This species and its control are described in detail on page 285 under Potato Pests.

ORTHOPTERA

Wingless grasshopper *Phaulacridium vittatum*

Tableland crops are sometimes invaded in dry summers by hordes of these hoppers. They move from their natural host plants, when they dry out, and may devour the crop on a face.

This pest and its control measures are described on page 111 under Apple Pests and page 275 under Pea Pests.

DERMAPTERA

European earwig *Forficula auricularia*

Importance and Distribution This introduced pest, which was first recorded in New South Wales in 1934, may be important in some seasons in many parts of the tablelands. The earwigs attack many fruits and vegetables, and may become a nuisance when they invade houses.

Conditions for Infestation This species needs cool temperatures and relatively high moisture.

Description and Life History The active flattened adult earwig is brown and 12 millimetres long, and has a pair of wings folded under short wing covers. At the end of the body there is a pair of prominent horny processes, the forceps. On the back of the abdomen there are pores from which the earwig can eject an offensive liquid. Evans (1943) recorded that in Tasmania there is only a single complete generation per year, each female laying two batches of eggs – the first in spring and the second during early summer. They are laid in small nests in the soil, and the females guard the developing eggs and young. Evans stated also that there are six nymphal stages. During the first and second stages they do not wander far from their nests and will hurriedly retreat to them if disturbed. They may wander further afield later, but feed only at night and rest underground during the day. The adults also are largely nocturnal.

Plants attacked Earwigs attack all sorts of vegetables, and have also been known to damage garden and fruit tree flowers. They are known to eat such different foods as seedling roots,

fallen fruit, dead and living insects and food for humans, such as flour and meat. They are particularly attracted to lettuce.

Injury Earwigs nibble foliage until it has a ragged appearance, and invade lettuce hearts which they spoil by their presence and excrement.

Dispersal Although the adults have wings they seldom fly and move mainly by crawling. They hide by day, particularly in soil, so they are often transported in pot plants and bulbs.

Control measures Earwigs may be controlled by lindane-bran bait, or carbaryl 0.25 per cent spray, or traps such as upturned flower pots filled loosely with straw or crumpled paper, or grooved boards tied with the grooves together and standing upright against trees, walls, or some other support. Traps must be examined every few days and the earwigs in them shaken into kerosene or sump oil. The carbaryl spray should be applied to walls, paths and the bases of fences, and it will kill the earwigs crawling on them for a considerable time.

ARACHNIDA — ACARINA

Red-legged earth mite *Halotydeus destructor*
Blue oat mite *Penthaleus major*

Lettuce crops grown in autumn, winter or early spring in the inland districts are often attacked by these mites. They have round blue-black bodies and reddish legs. They feed at night or on dull days, and will quickly drop from the plants when approached. Their feeding makes white patches on the leaves that may rapidly cover whole leaves. The injury is often mistakenly attributed to frost.

Earth mites are discussed in more detail on page 275 under Pea Pests.

Spider mites *Tetranychus* spp.

Lettuce grown without irrigation may be infested by these mites, especially if neighbouring land has recently been used for beans or cucumbers which suffered damage from these pests.

Further details and recommendations for control are given on page 236 under Bean Pests.

MOLLUSCA
GASTROPODA — SIGMURETHRA

Common garden snail *Helix aspersa*
Reticulated slug *Deroceras reticulatum*
Brown slug *Deroceras caruanae*
Black-keeled slug *Milax gagates*

These pests often damage lettuce severely after prolonged wet weather. They eat large ragged holes in the leaves, and contaminate the hearts with their excrement and slime, and, especially slugs, with their presence amongst the leaves. Sound-looking lettuces, on being opened, may reveal one or more repulsive slugs deep within the hearts.

More details will be found on page 82 under Citrus Pests and on page 239 under Bean Pests.

Onion, shallot, leek, garlic and chive pests

Onions are the most important crop in the group which includes shallots, leeks, garlic and chives. Most of the commercial crops of onions are grown in south-western New South Wales at Griffith and Jerilderie. The others are produced in small plantings in the Murrumbidgee Irrigation Area and in the Sydney market garden areas.

Onions are irrigated in all of the plantings. They are usually seeded directly into the field between May and early August. Some are planted earlier in market gardens and home gardens. Harvesting is done in summer or early autumn.

Onions and the related crops are attacked by only a few insect pests – the significant pests being the onion thrips and the onion maggot. Incidental pests that cause some harm from time to time include the vegetable weevil and cutworms. Rutherglen bug can sometimes do considerable damage in onion seed crops.

An account is given on pages 271 to 273 of the pests of onions and related plants listed below.

ARTHROPODA
INSECTA — LEPIDOPTERA

Cutworms *Agrotis* spp.
Cluster caterpillar *Spodoptera litura* (Fabricius)

DIPTERA

Onion maggot *Delia platura* (Meigen)

COLEOPTERA

Vegetable weevil	*Listroderes obliquus* Klug

THYSANOPTERA

Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

Rutherglen bug	*Nysius vinitor* Bergroth

ARACHNIDA ACARINA

Bulb mite	*Rhizoglyphus echinopus* (Fumouze and Robin)

INSECTA LEPIDOPTERA

Cutworms *Agrotis* spp.

When onions are planted in land previously infested with weeds, the young plants may suffer from cutworm attack. Leaves are nipped off during the night and the severed parts are found lying on the soil beside the damaged plants. A search in the soil will usually reveal one or more dark turgid soft grubs. They may be grey-green, brown to black or even pink. They curl in a circle when uncovered.

Cutworms and their control are described in greater detail on page 221 under Bean Pests.

Cluster caterpillar *Spodoptera litura*

This pest sometimes attacks leeks and shallots. The caterpillars hatch in late summer from clusters of eggs that are covered with a layer of brownish scales from the body of the female moth.

The young larvae remain together and feed in groups, grazing the surfaces of the leaves. Later the larger caterpillars feed singly and chew big holes in the leaves.

Control measures If control is required, it is achieved by spraying with diazinon 0.05 per cent.

Cluster caterpillar is described in more detail on page 251 under Cruciferous Pests.

DIPTERA

Onion maggot *Delia platura*

These maggots attack field-seeded onions or seedlings in the seedbed, and may cause much thinning-out of the stand. Such infestations have occurred in the autumn in various parts of New South Wales. The trouble has commonly been associated with the use of organic fertilizers like bonedust, blood and bone or animal manures. Damage has also been seen where a heavy green manure crop was ploughed in shortly before the onions were planted. It appears that the flies are attracted to such situations, especially if the soil is sandy. Where there is a danger of onion maggot attack, the use of only inorganic rather than organic fertilizers has resulted in freedom from infestation.

The first sign of attack is when the young plants suddenly wilt and collapse. An examination of the base reveals holes chewed in the underground stems, which may be hollowed out and rotting. The injury is caused by small white maggots, about 6 millimetres long, which may be found in the stems or in the soil nearby. The brown barrel-shaped pupae may also be found in

the soil. The grey adult flies are slightly hairy and about 5 millimetres long. They lay their eggs on the soil, and the resulting maggots feed on organic matter and seedlings.

Control measures Chemical control of onion maggots in onions has been achieved by spraying with diazinon 0.05 per cent just after emergence, and again ten days later.

Onion maggot is described more fully on page 228 under Bean Pests.

COLEOPTERA

Vegetable weevil *Listroderes obliquus*

Larvae of this beetle occasionally damage onions, but usually not to an important extent. The trouble is only likely to occur where the crop has been planted in land hastily prepared after weeds. Attack occurs in late autumn and winter. The young grubs chew small holes in the sides of leaves and in central shoots. Later the larger grubs can chew out big holes. The grubs usually feed at night, and retire to the soil by day. Occasionally the larvae are found inside the hollow onion leaves, but they may die in this very humid situation.

Control measures Control depends primarily on avoiding infestation by very thorough land preparation, which is always an important requirement for onions. Where the presence of vegetable weevils is suspected control has been obtained before planting by boom spraying with DDT or baiting with lindane-bran bait.

The pest and its control are discussed further on page 253 under Cruciferous Pests.

THYSANOPTERA

Onion thrips *Thrips tabaci*

Importance and Distribution This insect is found in all onion-growing areas of the world. It also attacks very many other crops and weeds. In New South Wales it has caused serious damage to onions; yield increases as high as 75 per cent have followed the application of successful control measures (Hely, 1946).

Conditions for Infestation Warm dry weather is favourable to the thrips, and hardly any trouble will arise in cool rainy seasons. Regular irrigation of the crop also reduces thrips injury.

Plants attacked Almost all vegetables, many garden plants and weeds may suffer considerable damage from this thrips in dry weather. In addition, it is the main vector of a virus disease, spotted wilt, which is important in tomatoes as well as in other vegetables and garden plants.

Description and Life History The female is a tiny light or dark brown insect 1.3 millimetres long, with two pairs of narrow grey wings fringed around the margin with fine hairs, and the male is somewhat smaller. The wingless and sluggish young, which are creamy in colour, cluster at the bases of central leaves in the throat or 'chit' of the plant, grazing the tender surface. The adults visit that situation only to lay eggs. The adults spend most of their time on the exposed upper surfaces of leaves where they feed by piercing the epidermal tissues and sucking the sap. They are described in some detail by H. Vevers Steele (1935).

The eggs hatch after about a week. The young or nymphs pass through four stages, the last two of which are spent in the soil without feeding. Although there are males, which are winglers, the females can reproduce without mating. Many generations are produced during a year, and all stages are found on onions at any time.

Injury Thrips injury in onions takes the form of silvering or 'blasting' of the foliage, and can be seen in almost every onion bed. When gross feeding occurs, the leaves tend to become buckled or twisted and die back from the tips. The plants can be dwarfed or killed. As a result of heavy attack, yield is reduced and the quality of the onions down-graded.

Dispersal Although thrips have apparently fragile wings, they are quite strong fliers, capable of easy flight, and readily become wind-borne.

Control measures Efficient control can be obtained by spraying with dimethoate 0.03 per cent or diazinon 0.05 per cent. Spraying should begin as soon as nymphs are seen on a periodic inspection of the throats of the plants. Further treatments may well be needed, depending on the rainfall and temperature. Three or four applications in the life of the crop should be adequate even under conditions which suit the pest.

HEMIPTERA

Rutherglen bug *Nysius vinitor*

Onion crops may be invaded in spring by adults and nymphs of this small active grey-brown bug when they swarm out of their breeding grounds amongst weeds in hot dry weather. They can cause plants to wilt by their mass attack, and can destroy immature seed heads.

Control measures Control has been obtained by spraying with maldison 0.06 per cent, or mevinphos 0.05 per cent. Special precautions must be observed when spraying with mevinphos because of its high toxicity.

Rutherglen bug is described in more detail on page 163 under Grape Pests.

ARACHNIDA ACARINA

Bulb mite *Rhizoglyphus echinopus*

Importance and Distribution Bulb mites have been spread around the world. They are important pests of many flower bulbs and attack onions and related vegetables. They do not usually cause much harm to onions in New South Wales, although they may occasionally damage a crop in store and have been known to cause severe injury to commercial crops of chives.

Conditions for Infestation Warm moist conditions suit the mites, and an important increase in population and damage development may take place in onions in store.

Plants attacked Many flowering bulb plants, as well as onions and related plants, are subject to attack. Amongst the most commonly affected are amaryllis, narcissus, hyacinth, lily, daffodil and jonquil.

Description and Life History Mites at all stages will be present in an infestation, and they are 0.5 to 1 millimetre long. The adults are oval, somewhat translucent, and white with brown or pink legs. The adult female may live for one or two months and lay more than 100 eggs behind the bud scales. The immature mites are the most destructive.

Under certain conditions, a heavily-chitinized, non-feeding, but very active, immature stage (known as the 'hypopus') may occur and last for about two weeks. The hypopus has a group of suckers on the lower side of the body which enables it to attach readily to insects, mice and other creatures, and thus be transported to new situations.

Injury Mites feeding within the bulbs cause them to break down and rot. The mites seem to prefer healthy bulbs, so they leave decaying bulbs in the soil to attack fresh ones. Plants grown from infested bulbs turn yellow and are stunted and sickly. The mites will be found in large numbers sheltering behind, or boring into, bud scales. In New South Wales, bulb mite injury is most likely to be seen in onions planted in the bulb form to produce seed, in shallots and garlic, and sometimes in severe infestation on chives. As chives may be propagated continuously by tufts, and shallots and garlic by cloves or bulbous sections, they are most likely to be damaged year after year, following the original infestation.

Dispersal Most distribution takes place by means of infested bulbs, but mite hypopi also play a part. Mites are also capable of moving in the soil from decayed to healthy bulbs.

Control measures Sanitation by burning damaged bulbs at digging or at planting time is important. Dipping bulbs for one minute at 51°C in lime-sulphur at between 0.4 and 0.8 per cent (polysulphides), or for three hours in hot water at 44°C, is effective in disinfestation (Metcalf, Flint and Metcalf, 1962).

Excellent control in chive beds has followed drench spraying with dimethoate 0.03 per cent.

Pea pests

Peas are grown in New South Wales both for the market as fresh green peas and for processing. Most of those for the fresh green pea market are grown in coastal districts in autumn, winter and spring and on the Central Tablelands in spring and summer. Peas for processing grow mainly in the Central West and on the Southern Slopes.

Peas have no specific pests, but there are several general pests which cause varying amounts of injury each year and sometimes do severe damage throughout large areas.

An account is given on pages 274 to 277 of the pests of peas listed below.

ARTHROPODA

INSECTA

LEPIDOPTERA	
Budworms	*Heliothis armiger* (Hübner) *Heliothis punctiger* Wallengren
Cutworms	*Agrotis* spp.
COLEOPTERA	
Spine-tailed weevil	*Desiantha caudata* Pascoe
A ground weevil	*Prosayleus dispar* Germar
THYSANOPTERA	
Onion thrips	*Thrips tabaci* Lindeman
HEMIPTERA	
Cowpea aphid	*Aphis craccivora* Koch
Potato aphid	*Macrosiphum euphorbiae* (Thomas)
ORTHOPTERA	
Wingless grasshopper	*Phaulacridium vittatum* (Sjöstedt)

ARACHNIDA ACARINA

Red-legged earth mite	*Halotydeus destructor* (Tucker)
Blue oat mite	*Penthaleus major* (Dugès)

MOLLUSCA
GASTROPODA SIGMURETHRA

Reticulated slug	*Deroceras reticulatum* (Müller)
Brown slug	*Deroceras caruanae* (Pollonera)
Black-keeled slug	*Milax gagates* (Draparnaud)

ARTHROPODA
INSECTA LEPIDOPTERA

Budworms — *Heliothis armiger*, *Heliothis punctiger*

These caterpillars are important pests of peas wherever the crop is grown, and sometimes cause heavy losses. The caterpillars may retard the growth of peas by eating young foliage, but the main attack is directed at flowers and fruit. When the infestation is heavy, the peas are eaten out of many pods. On the North Coast, pea crops in all stages may be attacked in March, April and May by *Heliothis armiger*. Peas are at their most susceptible after flowering starts and, in some areas, this period in the spring corresponds with the time when many moths are emerging from overwintering pupae.

Although the moths fly strongly it is probable that most damage to pea crops arises from moths bred locally, particularly on weeds or pasture legumes.

Control measures They may be controlled by spraying with methomyl 0.045 per cent or mevinphos 0.07 per cent. Great care must be exercised in using mevinphos because of its high toxicity.

For a more detailed discussion see page 219 under Bean Pests.

Cutworms — *Agrotis* spp.

These moths and their larvae, and methods of control are described on page 221 under Bean Pests.

COLEOPTERA

Spine-tailed weevil — *Desiantha caudata*
A ground weevil — *Prosayleus dispar*

Pea crops on the tablelands are sometimes damaged in spring by the larvae of these weevils (Anon, 1947). Damage by adults of one of the *Desiantha* species has been recorded in the Lower Murray area.

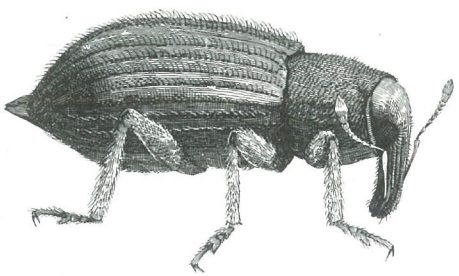
The larvae characteristically chew the stems of the pea seedlings close to ground level and sometimes make furrows up to 2.5 centimetres long in the stems. The seedlings wilt and die. The larvae are pale yellow, active, thick-set grubs about 6 millimetres long, and may be found in the soil close to the injured plants. They make earthen cells in the soil in November and pupate. In pasture they feed on the roots of subterranean clover.

The adult *D. caudata* is about 6 millimetres long and dark brown. The ends of the males' wing covers are produced backwards to form the small spine-like process which gives the species its common name.

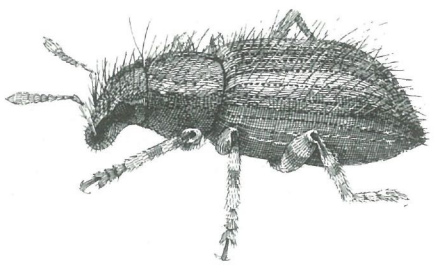
The adult *Prosayleus dispar* is also about 6 millimetres long, slightly hairy and grey-brown with small light and dark markings, and with two narrow, parallel, longitudinal white bands on the dorsal surface of the thorax.

It seems that the larvae of these weevils attack pea plants when they have been sown in an area that formerly carried the weevils' other food plants, notably subterranean clover.

Early and thorough preparation of pasture land on which peas are to be sown can largely avoid the trouble.



Spine-tailed weevil. (Length about 6 mm)



A ground weevil. (Length about 6 mm)

THYSANOPTERA

Onion thrips *Thrips tabaci*

Onion thrips are common throughout New South Wales and may be found wherever peas are grown. While they are present in all seasons, it is only in dry periods, after migration from nearby wilting weeds, that their damage to peas becomes important. In coastal districts, they are most likely to be troublesome in late spring. On the tablelands, they may do considerable harm in December and January in dry weather.

The thrips feed on surface cells and the injured areas become white. Coalescence of damaged areas, as the insects multiply, produces streaks and blotches. Eventually the plants may appear to be silvered more or less all over, and growth is seriously retarded. The pods which have been fed on are reduced in market value. Damage to flowers may cause them to drop. In extreme cases the plants are killed.

Control measures Maldison 0.06 per cent spray, or dimethoate 0.03 per cent, or diazinon 0.025 per cent may be used to control these pests.

Clean cultivation and the destruction of nearby weed growth should help to avoid thrips infestation early in the life of the pea crop.

This insect is described more fully on page 272 under Onion Pests.

HEMIPTERA

Cowpea aphid *Aphis craccivora*

Cowpea aphid attack on peas usually occurs in October and November, and is more of a problem on the tablelands than elsewhere in New South Wales.

Usually the only damage caused is a check to the crop, but flowering and podding may be reduced or even prevented. The attack is short lived, and the population dies out after migrations cease. However, the aphids may transmit the viruses of top yellows and mosaic diseases that will further depress yield (Grylls, 1972). The use of resistant varieties is described by Ballantyne and Pulver (1972).

Control measures If the invasion is likely to be serious, the crop should be sprayed with demeton-S-methyl 0.025 per cent, or dimethoate 0.03 per cent.

This insect is described more fully on page 234 under Bean Pests.

Potato aphid *Macrosiphum euphorbiae*

These small pale green aphids are globular and winged or wingless. They cluster on the undersides of the older leaves of pea plants and on younger growing tips. In a severe infestation they may be all over the plant. They cause some wilting and twisting of the leaves, and they retard growth to some extent. The heavy production of honeydew is objectionable. They also transmit virus diseases (Grylls, 1972).

Attack by this species may occur in spring or autumn. The aphids breed on many other crops and on weeds.

Control measures If the infestation seems to be important, it may be controlled by following the recommendations for cowpea aphid above.

This pest is described more fully on page 285 under Potato Pests.

ORTHOPTERA

Wingless grasshopper *Phaulacridium vittatum*

In the tablelands during the late summer and autumn, peas and other crops, notably cabbages, are sometimes invaded by swarms of these insects which rapidly eat the leaves and stems. They are grey-brown and grow to a length of up to 18 millimetres. They are troublesome in dry weather when a shortage of feed in their natural pasture habitat forces them to move, and fruit and vegetable crops may become affected.

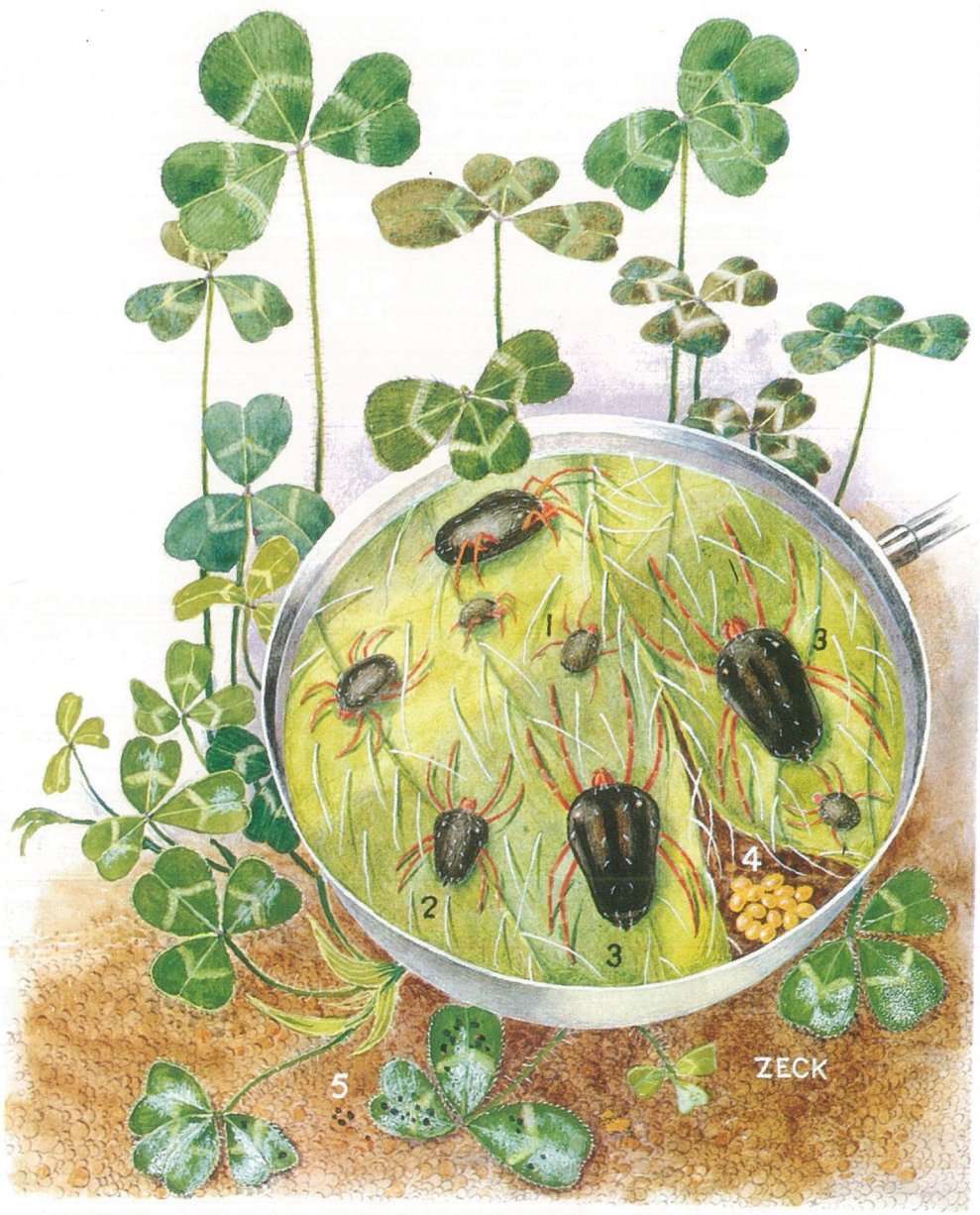
Control measures Control may be achieved in pea crops by spraying with dimethoate 0,03 per cent.

For further details of this pest see page 111 under Apple Pests.

ARACHNIDA ACARINA

Red-legged earth mite *Halotydeus destructor*
Blue oat mite *Penthaleus major*

Importance and Distribution These two earth mites are autumn, winter and spring pests of many crops. As vegetable pests they may be considered together. Red-legged earth mite is generally found only in the southern half of New South Wales.



Red-legged earth mite
Halotydeus destructor

1 First young stage (larva); **2** second young stage (nymph); **3** adult mites; **4** eggs on surface of soil; enlarged about twenty-two times. **5** Subterranean clover showing injury and mites feeding; actual size.

Blue oat mite is widely distributed, except in the Far West, but it is most often recorded causing damage in the North West Slopes and in the Hunter Valley. They are well-known pests of pastures.

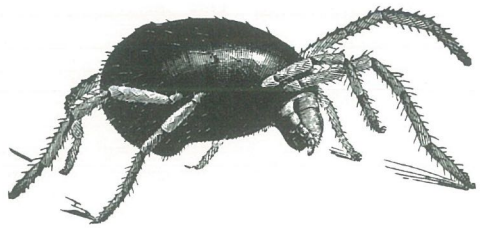
Conditions for Infestation Most damage occurs when good autumn rain is followed by dry winter weather. The combined effects of poor growing conditions and the feeding of the mites can severely check the crop. The injury is often attributed to frost. When rain stimulates the crop, the plants can tolerate moderate mite infestations without much harm.

Plants attacked A wide range of field crops, vegetables, flowers and weeds are suitable hosts for both mites.

In general, the red-legged earth mite prefers broad-leafed plants and legumes, whereas the blue oat mite, or as it is sometimes known, pea mite, does its most serious damage to grasses, especially oats (Greenup, 1967). Both can be important pests of peas.

Description and Life History Both mites are about 1 millimetre long. They have blue-black or black globular bodies and pink or red legs, and run actively on the plants. Adults have eight legs. The main differences in appearance between the species are: red-legged earth mite has a velvety black body; blue oat mite has a blue-black body, with its anus visible in a small red oval on the back towards the rear end.

The eggs of *Halotydeus destructor* are yellow-orange, and are laid in clusters on the undersurfaces of lower leaves or on the soil. The eggs of *Penthaleus major* are red-orange, later becoming straw-coloured, and are laid singly on leaves and stems or on the soil. The first-stage young have six legs and later stages have eight legs. The adult stage is reached after further moults. There may be several generations in the cooler half of the year. Adults of the later generation die in late spring, retaining unlaid eggs in their bodies. These eggs survive the summer and give rise to the new generation after the first autumn rains. If autumn rainfall is adequate, a big hatching of mite eggs results and the young are provided with abundant food plants. If such rainfall is followed by a dry winter, there will be many mites and relatively scarce food.



Blue oat mite. (Length about 1 mm)

Injury Both mites feed by puncturing the plant cells and sucking up the sap. They feed at night or, in cloudy weather, by day. The surface tissue turns white; with large numbers, complete leaves may be bleached. Seedlings may wither or have leaves curled up at the edges, and plants become dwarfed and have the appearance of being frost damaged. If peas are planted in ground which was weedy a short time before, the seedlings may be destroyed soon after they appear above ground.

Dispersal The mites can crawl over soil. Crop plants bordering weedy areas are frequently more seriously attacked than those further in to the field. Infestation of this type is common in pea crops. During summer, mites are dispersed on the hooves of stock while in the egg stage. Garden soils often become infested by being dressed with sheep manure.

Control measures

NATURAL Population numbers of this pest are strongly influenced by weather and they are attacked by predatory mites, but natural control is not reliable.

A long clean fallow before planting does much to reduce the danger of mite attack.

APPLIED Spraying with dimethoate 0.03 per cent is recommended to control these pests.

MOLLUSCA
GASTROPODA — SIGMURETHRA

Reticulated slug *Deroceras reticulatum*
Brown slug *Deroceras caruanae*
Black-keeled slug *Milax gagates*

Pea crops are sometimes attacked by slugs in wet weather, or where the crop is sown in low-lying damp situations and near heavily weed-infested ground.

The foliage is chewed in a ragged manner, usually leaving the main veins intact, and the lower leaves are the ones most affected.

Slugs hide in the soil during fine days and attack the plants at night. They may feed in daylight in rainy weather. A shiny viscid slime trail on plants and soil is a sign of slug activity.

Control measures Infestation in a crop often starts by invasion from nearby weedy ground. Control is achieved by the use of metaldehyde or methiocarb baits scattered through the infested area, or the application of Bordeaux mixture spray.

More details of control measures are given on page 239 under Bean Pests.

Potato pests

The essential requirements of potatoes during the growing period are cool conditions and ample moisture. In New South Wales many of the crops in coastal areas and most of those in the inland are irrigated. However, the main crop grows on the tablelands and is usually not irrigated. It is planted in late spring or early summer and marketed from June to August. Most of the coastal-grown potatoes are 'early' (planted from June to August) or 'late' (planted in February or March).

The coastal plantings are generally in small fields (about 4 hectares), while the areas in the tablelands are mostly larger (5 to 20 hectares).

Potatoes are attacked by at least 20 pests, but many are of only local importance. Potato moth may appear in all crops, and in some seasons causes severe damage. It is most destructive in dryland crops in dry seasons. Aphids are also important in some seasons because they are vectors of damaging virus diseases.

Control of potato pests usually depends on sprays, many of which are applied by low-volume boom sprays or by aircraft.

An account is given on pages 278 to 286 of the pests of potatoes listed on the next page.

ARTHROPODA

INSECTA LEPIDOPTERA

Potato moth	*Phthorimaea operculella* (Zeller)
Loopers	*Chrysodeixis* spp.
Cutworms	*Agrotis* spp.

COLEOPTERA

White fringed weevil	*Graphognathus leucoloma* (Boheman)
Vegetable weevil	*Listroderes obliquus* Klug
Twenty-six-spotted ladybird	*Henosepilachna sparsa vigintisexpunctata* (Boisduval)
Twenty-eight-spotted ladybird	*Henosepilachna vigintioctopunctata* (Fabricius)
African black beetle	*Heteronychus arator* (Fabricius)
Wireworms	Elateridae
False wireworms	Tenebrionidae
Flea beetles	Halticinae
Large pasture scarab	*Rhopaea magnicornis* Blackburn

THYSANOPTERA

Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

Potato aphid	*Macrosiphum euphorbiae* (Thomas)
Green peach aphid	*Myzus persicae* (Sulzer)
Vegetable jassid	*Austroasca viridigrisea* (Paoli)
Green vegetable bug	*Nezara viridula* (Linnaeus)
Rutherglen bug	*Nysius vinitor* Bergroth
Green mirid	*Creontiades dilutus* (Stål)

ORTHOPTERA

Wingless grasshopper	*Phaulacridium vittatum* (Sjöstedt)
Mole crickets	*Gryllotalpa* spp.

ISOPTERA

Termites ('white ants')	–

ARACHNIDA ACARINA

Spider mites	*Tetranychus* spp.
Broad mite	*Polyphagotarsonemus latus* (Banks)

Potato moth *Phthorimaea operculella*

Importance and Distribution This pest occurs throughout the world. In New South Wales it is the most important pest of the potato crop, and in dry seasons it may seriously reduce the total yield. Damage to potatoes in store may reduce the amount marketed for food as well as the numbers of seed potatoes available for the following season.

Conditions for Infestation Hot dry seasons favour this moth. The ground cracks with the expansion of the tubers and, if there is no rain, the cracks remain open. This gives the moths and grubs from the top growth access to the tubers, even when they are well below the surface. Under irrigation or with regular rainfall, the tubers remain covered by soil until harvested. Studies in Israel (Yathom, 1968) have shown that turgid plants, grown with irrigation, seem to be less attractive to the moth than wilted non-irrigated plants. More eggs were laid on the wilted plants and a higher percentage of them hatched.

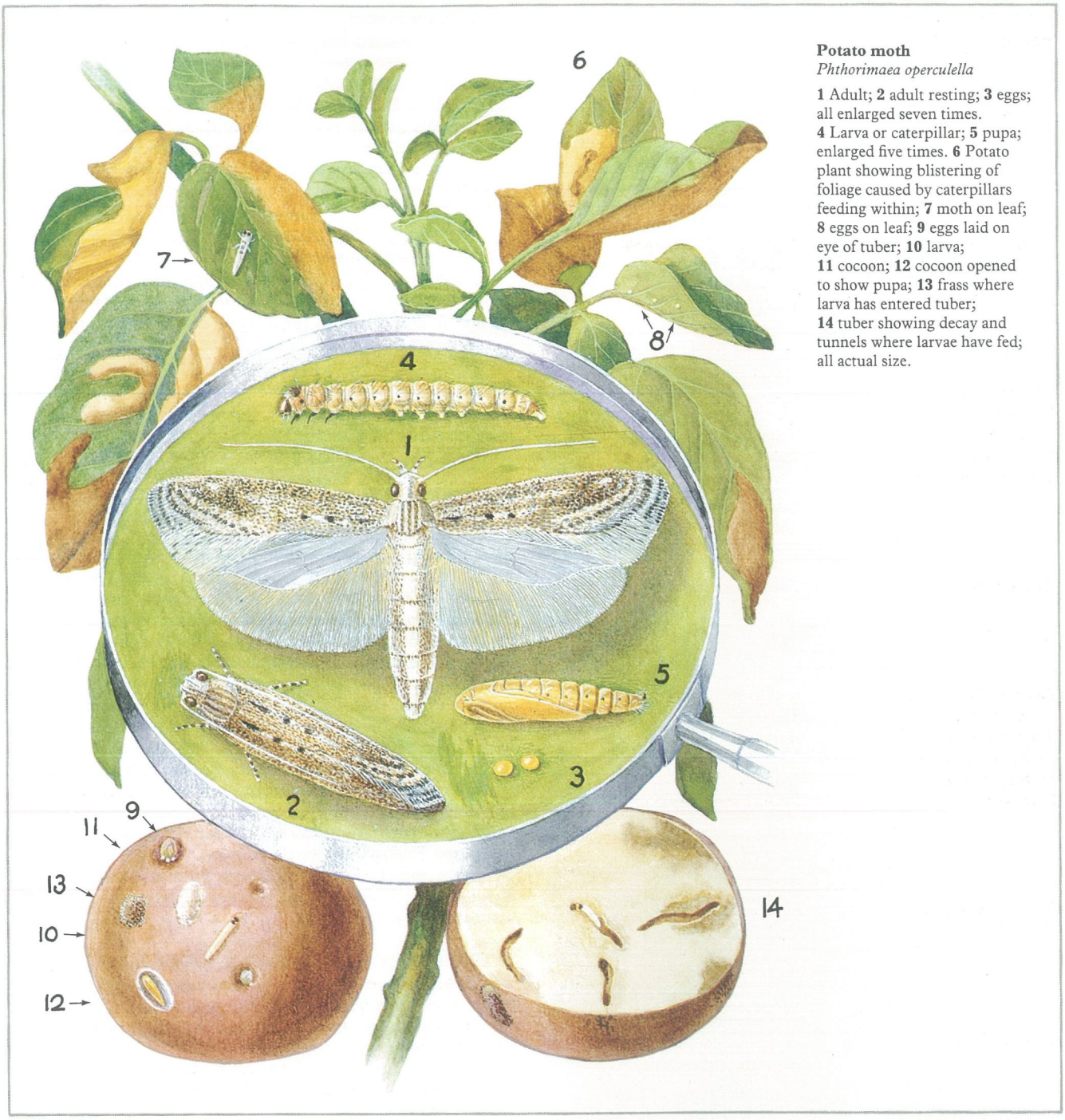
Plants attacked Potatoes, tomatoes and tobacco are commonly infested by potato moth, as are several solanaceous weeds including thornapple, false Cape gooseberry and the nightshades.

Description and Life History The adult moths, both male and female, are about 12 millimetres across the outspread wings, and brownish grey with tiny dark scattered markings on the forewings. The pale cream hindwings are bordered by a fringe of fine hairs. The moths remain quietly amongst the plants during the day, but run out of sight if disturbed; towards dusk they become active. They then fly readily, and deposit minute white eggs on the plants or tubers. On leaves, the eggs are usually laid singly on the undersurfaces; on tubers, they are laid in groups around the eyes or surface scars. Each moth can lay up to 100 eggs in two weeks. Incubation requires from a week in summer to several weeks in winter.

The larva usually crawls on the leaf for a short time and then mines into it. The eaten-out area becomes brown and brittle, with particles of frass enclosed in the blister. As the larva grows it eats its way into the leaf stalk and on into the stem where its feeding usually kills the terminal section. In the tuber, the larva tunnels just under the surface at first, but later penetrates more deeply. The larval stage lasts for about two weeks in warm weather, and much longer in winter. The full-fed larva is about 12 millimetres long and has a dark head. The body is greyish pink if the larva is in a tuber, and dark green if it feeds on foliage.

The mature larva leaves the plant or tuber and shelters amongst plant refuse on the ground, or between tubers that are in contact, or in folds of bags. There it spins a flimsy cocoon, often building in particles of soil or debris. Inside the cocoon the dark brown pupa, about 8 millimetres long, develops to the moth in a week or two. The life cycle is completed in about a month in summer, and there are several generations in a year.

On the North Coast in winter the time required from egg to adult is about ten weeks and the adults live for about three weeks. The moths breed freely in cull potatoes lying on the ground, in volunteer potato plants, and in weeds.



Potato moth
Phthorimaea operculella

1 Adult; **2** adult resting; **3** eggs; all enlarged seven times. **4** Larva or caterpillar; **5** pupa; enlarged five times. **6** Potato plant showing blistering of foliage caused by caterpillars feeding within; **7** moth on leaf; **8** eggs on leaf; **9** eggs laid on eye of tuber; **10** larva; **11** cocoon; **12** cocoon opened to show pupa; **13** frass where larva has entered tuber; **14** tuber showing decay and tunnels where larvae have fed; all actual size.

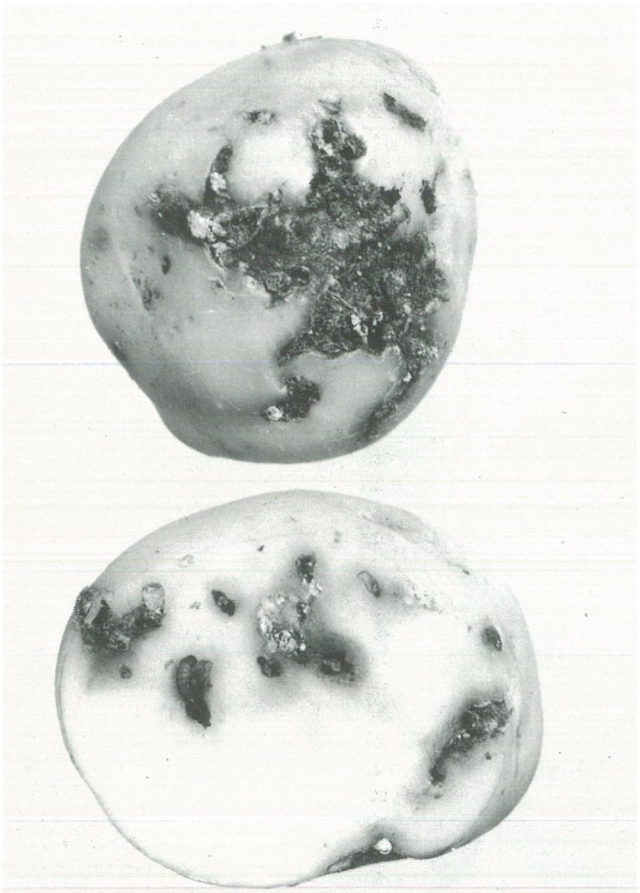
On the tablelands it is unlikely that larvae or eggs could survive the winter, but pupae and adults do so. Even in store, conditions for tablelands' potatoes are too cold for the larvae to feed, and in the field cull potatoes become frosted and rotten (Lloyd, 1943).

Injury These insects damage the plants above ground and the tubers in the soil and, later, in store. In late spring, particularly in coastal areas, the plants may die off prematurely with a considerable loss in yield, but the damage to tubers is more important. Field infestation occurs when soil cracks allow the larvae or moths to reach the tubers; weather and soil type influence the degree of infestation. Where conditions happen to suit the pest, damage to 80 per cent of tubers may occur. There is also loss after digging if the tubers are not bagged promptly and removed from the field. Where moths and larvae are abundant, experiments have shown that a delay of one hour in bagging tubers after digging can more than double the level of infestation (Lloyd, 1944). A heavy infestation in the bags, if neglected, may reduce the contents to a decaying mass.

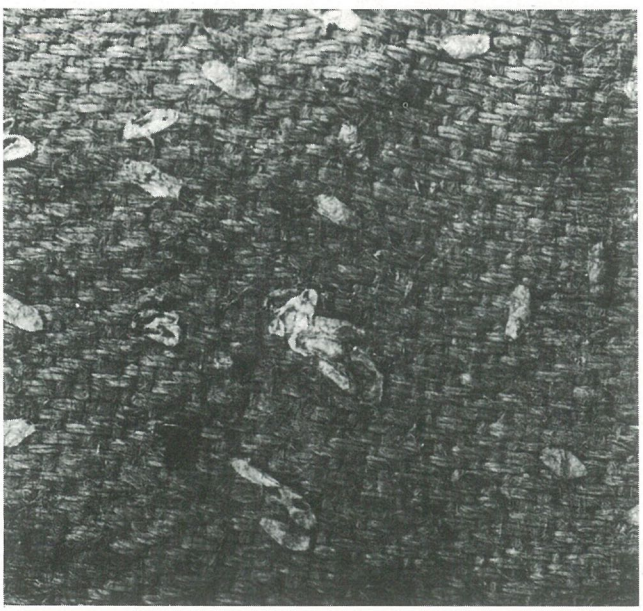
Dispersal The moths fly readily at night. They are also wind-

borne. Clean crops are commonly infested from dirty crops several hundred metres away.

Dispersal from one locality to another is most likely to be by the movement of infested tubers, bags and other containers.



Potato tubers damaged by potato moth.



Potato moth cocoons on inside of potato bag.

Control measures

NATURAL Several wasp parasites have been introduced to Australia as possible agents for the biological control of the potato moth (Wilson, 1960; Anon, 1970). Three are well established: *Apanteles subandinus* Blanchard occurs commonly from southern Victoria to northern Queensland; *Copidosoma koehleri* Blanchard and *Orgilus lepidus* Muesebeck are also widely established, but are better adapted to the warmer areas (Anon, 1970).

APPLIED Good control of infestation in potato foliage was given by DDT spray or dust, until the moth developed resistance to DDT. Azinphos-ethyl 0.04 per cent is now recommended and will give excellent control.

In tablelands' crops, two or three applications of the spray are usually necessary. The first application should be made when the moths are seen flying in the crop or caterpillars are noticed on the leaves, usually late in January. The second treatment should be given two or three weeks later. A third treatment may be needed after another three weeks or so, if moths are seen. These measures should give good protection to the plants and result in there being only slight damage to the tubers, or no damage at all. If an untreated crop is near a treated crop, the latter may suffer tuber damage late in the season from invading moths. For this reason all crops should be treated. Spraying at the first sign of infestation should be a routine practice each year.

In coastal crops treatment is not as essential, partly because most harvesting is done at an earlier stage in the growth of the plants. However, at least one treatment may be necessary.

Much can be done to reduce loss from potato moth by adopting sound agronomic and cultural methods, as well as by taking care in handling and storing the crop. The moth invariably appears earlier and does more damage in areas which grew potatoes in the previous year than in areas used for another purpose in that year. Potatoes should not follow potatoes. Every effort should be made to maintain the humus content of the soil by rotating with pastures and by growing potatoes in the same piece of land only one year in every five or six. Humus-rich soil cracks less readily on drying than does an overcropped soil low in humus. Deep planting (15 centimetres) reduces tuber damage, while clean cultivation and the destruction of self-sown potato plants and solanaceous weeds reduces moth populations. The collection and destruction of rejected tubers in the field and about the shed after harvest is most desirable to prevent the carry-over of moths.

Recommendations on hilling are as follows (Lloyd, 1950).

- ☐ Hilling must be done late in the season when the tubers are large but before they have become exposed. In tableland main crops this is usually in about mid-March and fifteen or sixteen weeks after planting.
- ☐ A large wide hill with the soil thrown well up around the bases of the plants is necessary.
- ☐ The rows must be at least 1 metre apart.
- ☐ The rows should be uniformly placed; plants out of line will be damaged by the hilling implement.
- ☐ The crop must be free from tall weeds, as they tend to stop soil thrown up by the hiller from falling around the bases of the plants.
- ☐ Hilling must be done quickly and at the right time.

Good hilling at the right time substantially reduces infestation in the harvested tubers, without loss of yield.

At harvest the potatoes should be bagged, and the bags sewn up and removed from the field, as soon as possible. Potato tops should **never** be used to cover bags standing in the field.

Seed and table potatoes may be protected in storage by thoroughly dusting them with rotenone 0.75 per cent (250 grams per bag). Even though this does not kill all the larvae feeding in the potatoes, it prevents further development of the infestation. Such infested seed may be used for planting if one or more eyes per tuber are intact. Table potatoes may also be kept in cold storage which prevents larval development (Passlow and Rigby, 1967).

Loopers *Chrysodeixis* spp.

Potato crops, especially in the Hunter and Hawkesbury Valleys, are attacked in some seasons by loopers which may do extensive damage in a short time.

Loopers feed mainly on the undersides of leaves and are difficult to see until the damage becomes obvious. Pellets of dark green excrement which fall on to lower leaves may be more obvious than the pale green caterpillars. When full-fed, the caterpillars pupate in white silken cocoons in the folds of leaves or on the undersides of leaves. They are most troublesome in spring-crop potatoes.

Control measures Control is not easy, as it is necessary to cover adequately the undersides of leaves. Endosulfan 0.07 per cent spray is recommended. Mevinphos 0.07 per cent spray will give a good kill but has no residual effect, and great care must be exercised when using this highly toxic material.

Further details will be found on page 223 under Bean Pests.

Cutworms *Agrotis* spp.

Cutworms are often troublesome in potato crops, especially on the coast where potatoes are often planted to free the land of weeds for another crop. Significant weed growth may still be left to be dealt with by inter-row cultivation. Residual clumps of weeds often shelter many cutworm larvae which then move to the crop plants and chew off the growing stalks at ground level. They may also chew holes in the lower leaves. This injury may be important in the early stages of establishment.

Control measures Control may be achieved by using lindane-bran bait or endosulfan 0.07 per cent spray, applied before the shoots appear, or when the injury is first seen.

Life history and control of cutworms are described on page 221 under Bean Pests.

White fringed weevil *Graphognathus leucoloma*

Importance and Distribution This insect, a native of South America, was first recorded in New South Wales in 1932 attacking lucerne in the Hunter Valley (Wallace, 1940). It is now recognized as one of the most important lucerne pests, and occurs commonly throughout the coastal districts, on inland river flats and in irrigation areas. Potatoes sown in land which has been under lucerne are sometimes attacked in the spring by the larvae of this weevil.

Conditions for Infestation Vegetable crops will soon be attacked if they are planted in newly-worked ground that was previously infested and still contains the partly-developed larvae.

Plants attacked The larvae require tap-rooted or fleshy-rooted species for their development. The adults will feed on a very wide range of plants. Lucerne is the favoured host, but potatoes, carrots, cabbages, beans and cucurbits are also susceptible to serious injury by the larvae, as are many kinds of weeds, ornamentals and even young fruit trees.

Description and Life History The adults are slaty grey with a short broad snout, and 10 to 13 millimetres long. A white band around the edge of the wing covers gives them their common name. The wing covers are fused together and the insect cannot fly. No males are known. All adults lay fertile eggs.

Adults emerge from pupal cells in the soil from late November to April, usually with a peak in numbers in February. They may live for several months and each may lay more than 1000 eggs. These are oval and about 1 millimetre long. They are laid in batches of 20 on, or just under, the soil surface or stuck to soil trash. Young larvae hatch after two weeks and burrow in the soil. They are legless grubs, white or grey with brown heads, wrinkled and slightly curved, tapering from behind the head to the hind end. They reach a length of about 13 millimetres. They are found mostly at depths of 5 to 15 centimetres below the soil surface but some may go deeper.

The larvae feed for many months (slowly in the winter) before becoming full-fed in the late spring when they form cells in the soil and pupate.

Injury The larvae do most of the damage. They can severely damage young plants and gnaw furrows or pits in potato tubers.

Potato tubers damaged by white fringed weevil larvae.

White fringed weevil
Graphognathus leucoloma

1 Eggs; enlarged about eight times. **2** Larva; **3** pupa; **4** adult; all enlarged about five times. **5** Larva attacking root of lucerne; **6** pupa; **7** adult weevil; all actual size.

Infestation is usually patchy. In late summer the adults sometimes migrate to potato crops, from nearby weedy areas, in numbers great enough to strip the leaves.

Dispersal Although the beetles cannot fly they have great powers of dispersal. Individuals have been shown to crawl hundreds of metres in a lifetime. They are hardy and can hide in hay bales, packages and many sorts of farm produce.

Control measures It is thought that abnormally high rainfall kills many larvae. After the excessively wet years in New South Wales in the early 1950s no important white fringed weevil damage was reported for several years.

Ground where the weevil is thought or known to be should be thoroughly prepared in the autumn and sown to a cereal such as oats at a high seeding rate, before it is used for susceptible crops like vegetables or lucerne.

When an attack is discovered, seedlings have been protected by jetting the soil at the base of each one with DDT 0.1 per cent.

Occasionally the adult beetles may invade a crop in numbers great enough to cause damage, when spraying with azinphos-ethyl 0.05 per cent might be expected to control them.

Vegetable weevil *Listroderes obliquus*

On the North Coast, in spring, potato crops may be attacked by these grey-brown weevils which can quickly strip the plants. They feed at night and shelter in the soil by day. During the winter, crops may suffer some attack by larvae that climb to feed on the lower leaves and stems, but this damage is not serious, and the plants grow away from it. Usually the adults invade the crop from headlands and adjoining country where they have bred on weeds, such as capeweed and marshmallow. Potatoes are often used on the coast as a land-cleaning crop without completely thorough preparation of the land, and because of this there may be a population of emerging weevils right through the field, or in patches, in October and November.

Control measures Control has been readily achieved by applying DDT 0.1 per cent spray to the plants attacked and to the soil beneath them when the injury is seen. Often it is necessary to treat a relatively small part of the crop, but the vegetation from which the weevils are moving should also be treated.

Further information on vegetable weevil is given on page 253 under Cruciferous Pests.

Potato plant damaged by vegetable weevil.

Twenty-six-spotted ladybird *Henosepilachna sparsa vigintisexpunctata*

Twenty-eight-spotted ladybird *Henosepilachna vigintioctopunctata*

Potatoes are commonly attacked by the larvae and adults of these leaf-eating ladybirds. *Henosepilachna sparsa vigintisexpunctata* is the more usual species found on potatoes and related plants. Usually the infestation becomes severe only when the plants are ageing and little harm is then caused to the tuber yield. If the pest population builds up quickly on a young crop, however, considerable injury results. The adults feed mainly on the upper surface of the leaves and the larvae underneath. As the chewed patches of tissue between the leaf veins enlarge, run together and turn brown, the plants may appear as if scorched by fire.

Control measures For control, thorough spraying of the upper surfaces and undersurfaces of the leaves with carbaryl 0.1 per cent is recommended.

Further details of these insects are given on page 262 under Cucurbit Pests.

Potato leaf damaged by leaf-eating ladybird.

Leaf-eating ladybird larva on damaged potato leaf. (Length of larva, when fully developed, is about 6 mm)

African black beetle *Heteronychus arator*

Coastal potato crops, on land recently under paspalum or adjoining such pasture, are often attacked in spring by the black beetle adults. One or more stems on individual plants suddenly wilt and collapse. On examination of the base, one or more stout shiny black beetles, about 12 millimetres long, will be found. These beetles gnaw the bases of the stems just below ground level and tear the tissues, leaving the injured part looking like teased rope. Beetles may also damage the eyes of setts in the ground, and they may bore into new tubers causing round rough-edged excavations that may lead to rotting.

The beetles lay eggs in the soil in spring and the curl grub larvae feed on organic matter and grass roots. The new adults emerge early in the new year. They may cause some damage to autumn crops before becoming inactive and overwintering in the soil. After the winter the adults become active again and may severely attack potatoes from late August to early November, when they die.

Control measures Beetle damage to potatoes may largely be avoided by not planting where overwintering beetles may be expected in the soil, and not planting near pasture of mat-forming grasses such as paspalum, carpet grass, kikuyu and buffalo. If such land must be used for potatoes, it should be cultivated a year earlier and kept free from mat-forming grasses and weeds, preferably by being used for a crop not susceptible to black beetle. Such crops include beans, peas, cowpeas, velvet beans, soybeans and vetches.

It is possible to get rid of the beetles by using lindane-broken maize bait, if they are seen in numbers during cultivation. When young potatoes have been attacked by African black beetle the damage has been stopped by jetting DDT 0.1 per cent into the soil at the base of each plant.

African black beetle is also discussed on page 295 under Tomato Pests.

Wireworms Elateridae
False wireworms Tenebrionidae

Potatoes sown in old grassland may be attacked by wireworms and false wireworms. They bore into tubers, sometimes right through, leaving narrow round holes. The possibility of attack is not easy to estimate. It is best to avoid the risk of damage, where these larvae are known to have been, by planting only in well-worked fallow land.

Some other details on these insects will be found on page 256 under Cruciferous Pests.

Flea beetles Halticinae

Importance and Distribution Flea beetles are sometimes numerous in coastal potato crops, but the damage does not generally reduce yield. Several species are involved. They all have very stout femora of the hind legs which enables them to jump like fleas. The potato flea beetle, *Xenidia picticornis* Blackburn, may be taken as being representative of the group.

Conditions for Infestation Dry weather in the spring seems to favour flea beetles.

Plants attacked Many different crops – including rhubarb, beans, and tomatoes – are attacked by this or related species, but the potato flea beetle is most commonly seen on potatoes or solonaceous weeds.

Description and Life History The adults are metallic-blue stoutly-built beetles about 3 millimetres long with a smooth but finely-pitted surface. They jump quickly when disturbed. They lay their eggs on the stems of the host plants, and the larvae, which reach a length of 12 millimetres, feed in the stems. They are pale cream in colour.

Injury The adults chew small irregularly-shaped holes in the foliage which, after heavy attack, may appear as though they have been damaged by fine shot. Wilting of stems as a result of boring by the larvae may occur, but this is uncommon.

Dispersal The beetles can fly.

Control measures If control is necessary, carbaryl 0.1 per cent spray should be effective.

Large pasture scarab *Rhopaea magnicornis*

Potatoes grown in friable red volcanic soil in North Coast districts of New South Wales are sometimes attacked by large white curl grubs. This may happen on newly-cultivated pasture land. The grubs that have been feeding on grass roots turn to the potatoes when their normal food source has gone. The potato stems may be severed below ground, or round deep holes with rough edges made in the tubers.

Control measures No control measures can be recommended once the attack has appeared. It is essential to avoid situations which are conducive to infestation. A long period of fallow is required between ploughing the pasture and planting a potato crop.

Pasture white grubs are described in greater detail on page 185 under Pineapple Pests.

THYSANOPTERA

Onion thrips *Thrips tabaci*

When the weather is very dry in spring, onion thrips sometimes infest potatoes. They may cause some stunting of the plants by feeding on the undersurfaces of the leaves, which then assume a dull silvery or bronzed appearance. They may also act as vectors of spotted wilt, a virus disease, that can infect many plants.

Injury is generally not important. Rain or irrigation soon enables the crop to grow away from the damage. If moisture stress continues and the harm promises to be serious, the thrips can be destroyed by spraying with dimethoate 0.03 per cent.

This pest is described on page 272 under Onion Pests.

HEMIPTERA

Potato aphid *Macrosiphum euphorbiae*
Green peach aphid *Myzus persicae*

Both these aphids may cause a good deal of injury to potatoes by sucking the sap and producing an abundance of honeydew. They do more important damage, however, by transmitting virus diseases such as leaf roll. The green peach aphid is the more important virus vector.

Potato aphids are green and about 3 millimetres long, with long slender cornicles. They are slow-moving and produce copious honeydew. Winged and wingless forms occur on the same plant. When the aphids are numerous, they cause the leaves to be turned down at the edges and undersized. They breed on many crops and weeds, and transmit a virus disease, yellow top, to tomatoes.

Green peach aphids are smaller than potato aphids and also breed on many crops and weeds. Wingless adults are green to pale yellow or pink. Winged adults are green with darker markings. They are more active and tend to infest the undersides of lower leaves as well as the new shoots. They transmit virus disease to many crops, and are the most important transmission agent for leaf roll of potatoes. During the warmer part of the year they reproduce viviparously, producing active young, not eggs, which grow into winged or wingless forms. Reproduction is extremely fast. In colder climates they are oviparous and overwinter as eggs on peach and nectarine trees. The eggs hatch in the spring; the new aphids feed on the tree foliage and produce winged forms that fly off, as the weather warms up, to start colonies on weeds and vegetables.

In sheltered situations in warm areas, green peach aphids sometimes feed and breed through the winter, for example, in home gardens and well-sheltered orchards. Winged forms of both species are ready to fly to and colonize potato plants as soon as they come above ground in early October.

Leaf roll virus is a 'persistent virus', which means that aphids remain capable of transmitting it once they have become infected. They take one day to pick up the virus from a diseased plant and then have to feed on a healthy plant for one day to give high levels of infection (Anon, 1970). During this period they can be killed by insecticide so that transmission is prevented. In potato crops, the spread of leaf roll virus mostly takes place as the potato shoots show above ground, and the infection is mainly from one potato plant to another. Most aphids arrive at the potato crop uninfected, but this is not the case if infected volunteer potato plants are growing nearby.

Usually seed potatoes are green-sprouted before planting, and infestation and infection can occur at that stage if the green-sprouting is done out of doors.

Aphid migrations by winged forms occur in spring and autumn. Large populations may build up on maturing potato crops.

Control measures Aphids of both species may be controlled, and the spread of leaf roll restricted, by the use of systemic insecticides. Spraying with demeton-S-methyl 0.025 per cent, or dimethoate 0.03 per cent, or thiometon 0.025 per cent is recommended.

Vegetable jassid *Austroasca viridigrisea*

These jassids are small yellow-green sucking insects about 4 millimetres long. They have the characteristic habit of moving sideways to avoid danger. When more seriously disturbed, they may fly out of a plant in a swarm. Young (wingless) and mature (winged) forms feed on the undersides of leaves, sucking sap and causing tiny yellow marks that give a stippled effect to the foliage. If numerous, they cause stunting of the crop. Dry weather suits the jassids. A good fall of rain or irrigation allows the plants to recover and suppresses the jassid population.

Control measures If control is considered to be necessary, spraying with dimethoate 0.03 per cent or maldison 0.06 per cent will be effective.

This insect is described on page 234 under Bean Pests and on page 297 under Tomato Pests.

Green vegetable bug *Nezara viridula*

These green shield-shaped bugs are about 15 millimetres long and sometimes attack potatoes in the spring. Overwintering adults move into the young crop, feed, and lay eggs from which rapid increase in population and serious damage may follow. The pest is not usually numerous nowadays.

Green vegetable bug is described in some detail on page 232 under Bean Pests.

Rutherglen bug *Nysius vinitor*

Large swarms of these grey-brown bugs, about 5 millimetres long, often invade potato crops in the spring. They can quickly induce severe wilting. Infestation is most likely in a dry spring after a mild winter. The bugs will have bred-up on weeds and, when these dry off, they move to succulent crops. Considerable damage can be done in a short time to potatoes.

Control measures Spraying with methidathion 0.04 per cent or maldison 0.06 per cent will be effective in killing the bugs.

Rutherglen bugs are more fully described on page 163 under Grape Pests.

Green mirid *Creontiades dilutus*

These slender light green insects are about 6 millimetres long, and are common in coastal potato crops in the spring. They move rapidly among the blossoms – both the mature form and the young wingless forms. On infested plants the buds when sucked turn yellow, dry out and fall. Blossom production may be suppressed. This appears to have no influence on tuber production and the pest is unimportant to potatoes. The bugs do, however, multiply on potatoes and often migrate later to beans where they can cause severe damage.

Further information on green mirid is given on page 231 under Bean Pests.

ORTHOPTERA

Wingless grasshopper *Phaulacridium vittatum*

Tablelands' potato crops often suffer attack during late summer by large numbers of these brownish grey grasshoppers up to 18 millimetres long. They generally move in to the crop on a face from adjoining pasture land. They may soon penetrate deeply into the field, leaving a trail of devastation. They can strip the foliage and leave bare skeletons of plants. This happens when they have bred-up on good pasture which has then dried off, leaving the hoppers without green feed.

Control measures Hoppers in the crop can be controlled by spraying with dimethoate 0.03 per cent.

More detail on life history and control is given on page 111 under Apple Pests.

Mole crickets *Gryllotalpa* spp.

These insects sometimes attack potatoes by surface-furrowing or boring holes in the tubers when the crop is nearly ready to dig. The damage is not seen in large commercial plantings, but occasionally causes concern in small gardens. Control of mole crickets in potatoes is rarely needed.

More details are given on page 299 under Tomato Pests.

Mole cricket. (Length about 3 cm)

ISOPTERA

Termites

Potatoes in freshly-cleared or incompletely-cleared land, or adjacent to bushland, are sometimes attacked by white wingless soft-bodied termites. Stems and tubers may become tunnelled and 'honeycombed', and reduced to spongy material with the skins still intact. Infestations start from a dead tree stump or log in the potato field or on adjoining land, the potatoes being reached through underground galleries. The outside rows of the plot are more likely to be attacked than others.

Control measures Control is possible by avoiding planting near active termite colonies which can be destroyed, if necessary, by treatment with chlordane.

ARACHNIDA ACARINA

Spider mites *Tetranychus* spp.

In hot dry seasons spider mites sometimes infest potato crops to an extent which causes the leaves to turn yellow and fall. Infested plants will be seen to have the lower surfaces of the leaves covered with fine grey webbing amongst which the tiny mites, and their globular colourless eggs, are visible. Control measures are rarely needed.

Spider mites, and control measures against them, are described on page 236 under Bean Pests.

Broad mite *Polyphagotarsonemus latus*

These mites have not been known to harm commercial potato crops in New South Wales, but are an occasional pest of backyard potatoes in coastal districts in warm humid weather. In Queensland, however, they are of significance commercially and it is thought that they became numerous following the regular use of DDT on the potato crop (Hooper, 1957). Injury to the leaves takes the form of bronzing or russetting of the undersurfaces, followed by in-rolling with a stunting of the growth, and often resembles injury from 2,4-D weedicide.

Control measures Sulphur dust has been recommended when damage to the leaves appears. Care must be taken to treat the undersurfaces.

Broad mite is described in more detail on page 79 under Citrus Pests.

Sweet potato pests

Sweet potatoes are grown commercially on the Far North Coast of New South Wales. The rest of the State has been considered to be too cold, but there is evidence that good yields could be expected in inland areas. On the tablelands the risk of frost injury to the tubers would be too great for the growing of this crop to be a practicable proposition.

Coastal growers usually propagate sweet potatoes by planting cuttings taken from plants which made growth early in the season. A special crop may be grown for this purpose; the vines of this crop are cut back in about July and then allowed to make new growth in early spring. Cuttings are taken from that new growth for the current year's planting which is made when there is no further danger of frost. Planting may be continued up to the beginning of January. A slightly different method of propagation is to bed roots in open ground in warm situations in late winter, and then take 'slips' when they are about 20 centimetres long.

Sweet potatoes have a distinct insect fauna as well as a few incidental pests that cause damage from time to time. The most important specific pests are the larvae of several hawk moths which devour the vines, and the sweet potato weevil that infests both tubers and vines.

An account is given on pages 287 to 290 of the pests of sweet potatoes listed below.

ARTHROPODA

INSECTA LEPIDOPTERA

Convolvulus hawk moth	*Agrius convolvuli* (Linnaeus)
Grapevine hawk moth	*Hippotion celerio* (Linnaeus)
Vine hawk moth	*Theretra oldenlandiae* (Fabricius)
Scrofa hawk moth	*Hippotion scrofa* Boisduval
Common armyworm	*Mythimna convecta* (Walker)
Cutworms	*Agrotis* spp.
Sweet potato leaf-miner	*Bedellia somnulentella* (Zeller)

COLEOPTERA

Sweet potato weevil	*Cylas formicarius elegantulus* (Summers)
Flea beetles	Halticinae

ARACHNIDA ACARINA

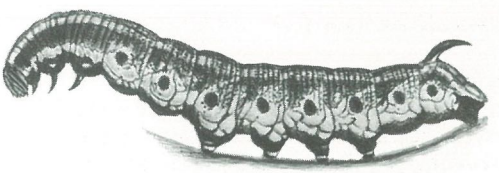
Spider mites	*Tetranychus* spp.

INSECTA LEPIDOPTERA

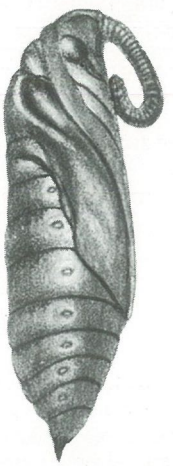
Hawk moths Sphingidae

Several different species of hawk moths attack sweet potatoes. The adults have a characteristic streamlined shape, with wings that are relatively narrow and pointed at the ends – the hindwings are markedly shorter than the forewings. The larva has a horn or spike projecting backwards from the eighth abdominal segment. The pupa has a slender tongue-case projecting from the front end and bent like a jug handle. This accommodates the long feeding tube of the future moth.

The larvae can do a lot of damage quickly and, although the damage can be seen easily, the larvae are well camouflaged. The large grey-green barrel-shaped pellets of excrement can fairly easily be seen on the lower leaves of the plant or on the soil.



A hawk moth larva. (Length about 9 cm)



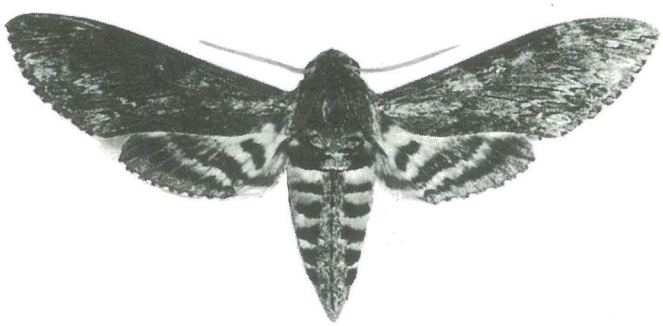
A hawk moth pupa. (Length about 6 cm)

CONVOLVULUS HAWK MOTH, *Agrius convolvuli* This is an introduced species. The eggs, laid singly on the plants, are bright blue-green, oval and 1 millimetre long. Young larvae eat the egg-shells after emerging, and then feed on the underside of a leaf. As they grow they eat larger holes and the foliage becomes torn and ragged. They reach a length of about 9 centimetres and may be green or brown.

The full-fed larva burrows into the earth and forms a cell about 10 centimetres below the surface in which the pupa forms.

It is brown and over 5 centimetres long. The adult moth, which is about 9 centimetres across the outspread wings, is of a general dark grey but speckled with white scales. The abdomen has a central grey stripe, and on each side of this line the segments are marked with pink and black.

The moth overwinters as the pupal stage in soil. There are two broods per year. The adults may be seen at dusk hovering about flowers, and sucking nectar.

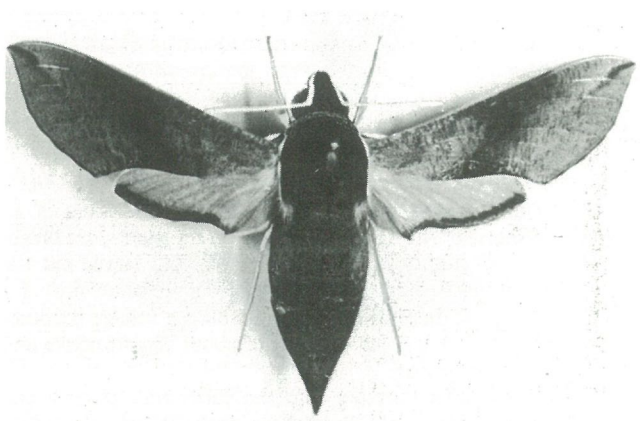


Convolvulus hawk moth. (Wingspan about 9 cm)

GRAPEVINE HAWK MOTH, *Hippotion celerio* This is an introduced species that feeds on sweet potatoes and related plants. The eggs are oval and bright green. The caterpillars are distinguished from other hawk moth larvae by having a large oval eye-spot on the fourth body segment as well as a smaller yellow spot on the fifth segment, and the horn on the rear end of the body is black and straight. The larvae reach a length of about 6 centimetres. They pupate in the soil. The moths are 6 to 7.5 centimetres across the outspread wings. The body is light brown with small silver markings. The forewings are brown, with a silver stripe or band extending from the tips towards the base of the wing. The hindwing is mostly brown but is bright pink near the body.

VINE HAWK MOTH, *Theretra oldenlandiae* The larvae of this species feed on grapevines and related plants, as well as on sweet potatoes and their relatives. The adults are similar to *Hippotion celerio*, but without the pink areas on the hindwings.

SCROFA HAWK MOTH, *Hippotion scrofa* This hawk moth sometimes attacks sweet potatoes. It has dull brown-grey forewings and orange-brown hindwings, and is 6 to 7 centimetres across the outspread wings.



Scrofa hawk moth. (Wingspan 6 to 7 cm)

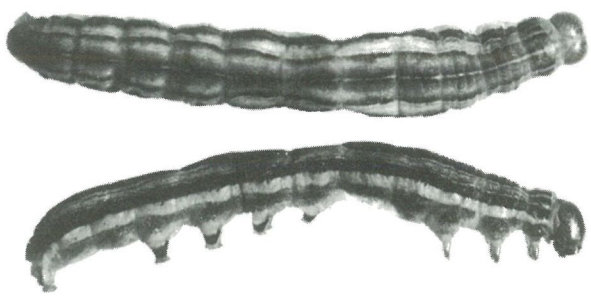
Control measures If the larvae of any of these moths are numerous enough to warrant control, carbaryl 0.1 per cent spray should be effective.

Common armyworm *Mythimna convecta*

Sweet potatoes are sometimes attacked in late summer or autumn by armyworms which swarm in large numbers and move on a front, eating most of the plants with which they come in contact. The caterpillars may be about 4 centimetres long.

Control measures They can be controlled by spraying with carbaryl 0.1 per cent.

Common armyworm adult. (Wingspan up to 4 cm)



Common armyworm caterpillars. (Length, when fully developed, about 4 cm)

Cutworms *Agrotis* spp.

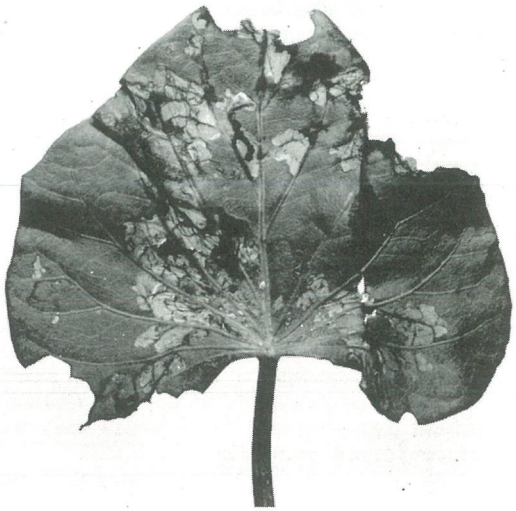
The caterpillars feed at night and hide in the soil by day. On sweet potatoes they attack the newly-planted cuttings or slips by cutting the tops off and leaving them lying on the soil. A search at the base of the plant usually reveals the grubs, which curl up when exposed.

The cutworms and their control measures are described more fully on page 221 under Bean Pests.

Sweet potato leaf-miner *Bedellia somnulentella*

These small green caterpillars occasionally do damage by mining in the leaves between the upper and lower leaf surfaces. They make light-coloured tunnels and, later, larger blisters. The damage is generally of no great significance.

Control measures If the infestation does assume serious proportions, spraying with diazinon 0.05 per cent should be effective.



Sweet potato leaf-miner damage.

Sweet potato weevil larva and pupae in infested tuber.

Sweet potato weevil. (Length about 6 mm)

COLEOPTERA

Sweet potato weevil *Cylas formicarius elegantulus*

Importance and Distribution This introduced weevil is likely to occur wherever sweet potatoes are grown in New South Wales. It is a serious pest on the North Coast. It attacks the plants in the field and continues to breed in tubers in store where it can do much damage.

Conditions for Infestation This pest thrives under warm moist conditions, and continues its activities in the winter in the subtropics.

Plants attacked Sweet potato, morning glory and related plant species are attacked.

Description and Life History The eggs are deposited singly in small cavities eaten out of the stem or tuber. White legless grubs, that grow to a length of 9 millimetres, eat down through the stem or into the tuber and feed for about three weeks. By feeding in the tuber they give it a bitter taste and offensive odour. They may honeycomb the tuber with tunnels full of excrement. Grubs may also be found in the cuttings or slips, in the vines and in roots before the tubers develop. The full-fed larva pupates in its tunnel and the adult eventually eats its way out. The adult weevil is a shiny, slender-bodied, ant-like insect about 6 millimetres long. The head, wing covers and abdomen are blue-black, and the prothorax and legs are bright red. The adults feed on the leaves and stems, and deposit eggs. Each generation is completed in five to six weeks in summer, but takes much longer in the cooler half of the year. Adults are long-lived – up to eight months.

Injury Tubers may be made unfit even for pig food in a surprisingly short time. The feeding of adults and larvae on cuttings and vines also does considerable harm.

Dispersal The adults can fly strongly and have been known to travel over at least 1.5 kilometres. This dispersal is of local importance, but the introduction of the pest to new areas is largely due to the movement of infested tubers, cuttings and plants.

Control measures Tubers, slips and plants from infested areas should be avoided when planting new areas. Strict sanitation measures must be observed where this crop is grown repeatedly, since breeding is continuous in tubers, old plants left in the ground, volunteer plants, any discarded plant or tuber material, or old seedbeds. All old vines should be burned and rejected tubers boiled. Pigs may be turned into sweet potato beds as soon as harvesting is finished to clean up tubers which were missed in the digging.

Overseas, damage has been controlled by DDT spray programmes, with dipping the planting slips in a DDT suspension as the first step (Sherman and Mitchell, 1953).

Flea beetles — Halticinae

These small metallic oval beetles can jump like fleas, and sometimes attack sweet potato vines in large numbers. Small irregularly-shaped holes are eaten in the leaves, which then look as though they have been peppered by fine shot. Flea beetles are controlled by spraying with carbaryl 0.1 per cent.

More details on flea beetles are given on page 284 under Potato Pests.

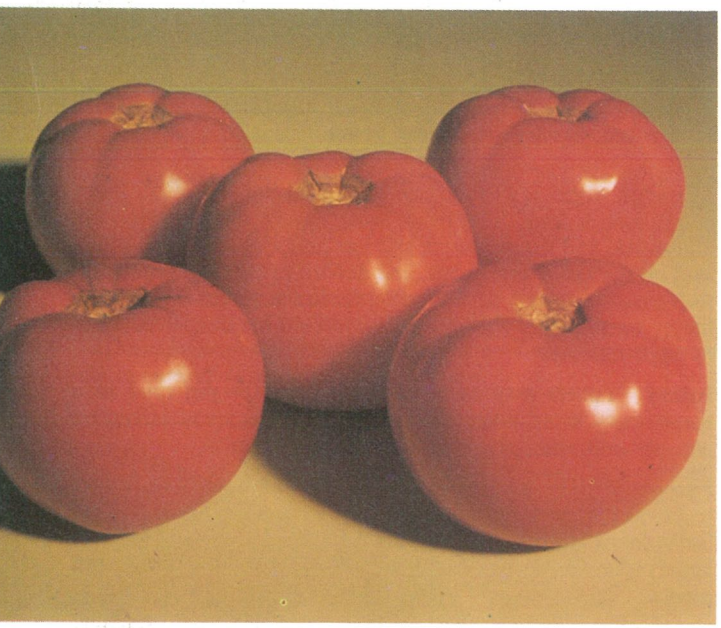
ARACHNIDA ACARINA

Spider mites — *Tetranychus* spp.

Spider mites can cause serious injury to sweet potato vines in hot dry weather. The leaves are first seen to be stippled and mottled. Later they wither and dry out, and defoliation can be severe. The undersides of the leaves are copiously webbed, and the mites, young and eggs may be seen under the webbing.

Spider mites are described in more detail on page 236 under Bean Pests.

Tomato, capsicum and eggplant pests



Tomatoes are grown commercially in almost all parts of New South Wales and are marketed in every month of the year. Fruit is produced in late winter and spring from field crops on the Far North Coast and from glasshouse crops mainly in the Sydney and Lower Murray areas. Early field crops grown under bags, to protect them from frosts, in the Leppington and Liverpool area of Sydney are harvested in spring. The mid-season to late crops are grown in the Sydney and nearby Hills district areas, and in the Central Coast district near Gosford. These fresh market crops account for approximately half the tomato-growing acreage in New South Wales. The remaining acreage grows tomatoes for processing under contract as main season ground crops in central-western and south-western districts.

Pest control is important in all areas. On the coast, a strict routine of treatments to combat pests and diseases is essential. Much care has to be taken in the cultivation of this relatively valuable crop and, on the coast, staking or trellising of tomatoes is the rule. This, amongst other advantages, simplifies the application of dusts and sprays. In each district, the planting distances, cultural methods and systems of staking or trellising are designed to suit the equipment to be used for pest and disease control. In coastal districts, routine applications (weekly or ten-day) of insecticide plus fungicide have to be strictly practised to ensure economic returns.

In inland districts the control of fungus diseases requires less attention and fewer applications of pesticides are needed, so ground crops are the rule. Although the strict routine treatments needed on the coast are not necessary, it is usual to spray against insects and/or mites for just as long as the spray equipment can be taken through the crop without doing much damage. In large plantings, the application of treatments by aerial spraying is the accepted practice.

Capsicums, which have become a popular crop in recent years, are grown mainly in the Mudgee and Lower Murray areas, with some production in the Murrumbidgee Irrigation Area, Sydney and North Coast. Eggplants are grown to a small extent on the coast and inland. As far as pests are concerned, these two vegetables may be considered with tomatoes.

An account is given on pages 291 to 300 of the pests of tomatoes, capsicums (peppers) and eggplants listed opposite.

ARTHROPODA

INSECTA LEPIDOPTERA

Budworms	*Heliothis* spp.
Potato moth	*Phthorimaea operculella* (Zeller)
Tomato stem borer	*Symmetrischema plaesiosema* (Turner)
Egg-fruit caterpillar	*Sceliodes cordalis* (Doubleday)
Loopers	*Chrysodeixis* spp.
Cluster caterpillar	*Spodoptera litura* (Fabricius)
Cutworms	*Agrotis* spp.

DIPTERA

Queensland fruit fly	*Dacus tryoni* (Froggatt)
Metallic-green tomato fly	*Lamprolonchaea brouniana* (Bezzi)
Ferment flies	*Drosophila* spp.

COLEOPTERA

African black beetle	*Heteronychus arator* (Fabricius)
Vegetable weevil	*Listroderes obliquus* Klug
Wireworms	Elateridae
False wireworms	Tenebrionidae
White fringed weevil	*Graphognathus leucoloma* (Boheman)
Leaf-eating ladybirds	*Henosepilachna* spp.

THYSANOPTERA

Onion thrips	*Thrips tabaci* Lindeman

HEMIPTERA

Vegetable jassid	*Austroasca viridigrisea* (Paoli)
Green vegetable bug	*Nezara viridula* (Linnaeus)
Rutherglen bug	*Nysius vinitor* Bergroth
Harlequin bug	*Dindymus versicolor* (Herrich-Schäffer)
Leptocoris bug	*Leptocoris mitellata* Bergroth
Green stink bug	*Plautia affinis* Dallas
Potato aphid	*Macrosiphum euphorbiae* (Thomas)
Green peach aphid	*Myzus persicae* (Sulzer)
Cowpea aphid	*Aphis craccivora* Koch
Greenhouse whitefly	*Trialeurodes vaporariorum* (Westwood)

ORTHOPTERA

Mole crickets	*Gryllotalpa* spp.
Black field cricket	*Teleogryllus commodus* (Walker)
Wingless grasshopper	*Phaulacridium vittatum* Sjöstedt

ARACHNIDA ACARINA

Tomato russet mite	*Aculops lycopersici* (Massee)
Spider mites	*Tetranychus* spp.

Budworms *Heliothis* spp.

These budworms, more commonly known as 'tomato grubs' on tomatoes, are undoubtedly the most important pests of tomatoes in New South Wales, and they occur wherever tomatoes are grown. The two species, *Heliothis armiger* and *H. punctiger*, are similar and can be considered together in this discussion.

Injury Budworms attack tomatoes from the time when the first flowers appear (rarely earlier) until the last fruits are forming. The larval chewing of buds and blossoms may cause them to fall, but the most obvious damage is to the fruit. When the very young larva enters the fruit, usually near the stem end, it makes a small pinhole that is not easy to see. If a larger grub moves from one fruit to another, it makes an entry hole which is 3 millimetres across or wider. Rotting inside the fruit generally leads to extensive breakdown.

Tomatoes damaged by budworms.

Control measures

NATURAL Budworms have natural enemies, but they cannot be depended upon to control the pest in a tomato crop.

APPLIED In all districts control measures are framed for these pests above all others, and in most places a routine schedule of treatments must be carried out.

Routine control measures should begin when the first flower buds are seen, and should be continued at weekly intervals until most of the fruit has set. DDT spray 0.05 per cent has previously been recommended for effective control, but it has been reported in recent years that the budworms appear to have developed some degree of resistance or, at least, a greater tolerance to DDT.

Spraying with endosulfan 0.07 per cent, or methomyl 0.045 per cent, or chlorpyriphos 0.1 per cent, or acephate 0.1 per cent is now recommended.

For more details see page 219 under Bean Pests.

Potato moth *Phthorimaea operculella*

In hot dry seasons in New South Wales the larvae of the potato moth sometimes cause considerable damage to tomatoes. This is most marked on the Far North Coast.

Tomatoes growing on land that has carried potatoes, where there are self-sown potato plants, are particularly likely to be infested. Damage may occur, even in the seedbed, if there are breeding sources for the moth nearby.

The small, brownish grey moths are about 12 millimetres across the outspread wings. They may be seen flying amongst the plants at dusk, but they remain inactive during the day. They lay the eggs on the undersides of leaves. The tiny caterpillars mine in the leaf blades, or may enter the leaf stalks and bore down into the stem. The leaf-mining produces brown patches that often look like blisters. The brown tissue withers and the leaf dies. The greyish pink caterpillars also bore into fruit at the stem end. They may also enter where two fruits, or a leaf and a fruit, are in contact, feeding just under the skin. It is common for such fruit to be invaded by rot organisms that cause the contents to break down and become watery. These grey 'water-bags' are usually a feature of potato moth attack on tomatoes.

Control measures On the Far North Coast where infestation by this pest is significant, azinphos-ethyl 0.04 per cent spray is recommended.

Further details of this pest will be found on page 278 under Potato Pests.

Tomato stem borer *Symmetrischema plaesiosema*

Importance and Distribution In New South Wales, this caterpillar is an occasional pest of tomatoes on the Central Coast from Sydney to Newcastle. Outbreaks are infrequent, but severe infestations have occurred at times in early spring following light infestation of autumn crops in that locality.

Conditions for Infestation Crops grown in warm coastal situations are the ones most likely to be affected.

Plants attacked Tomato is the only recorded host.

Description and Life History The moths are about 12 millimetres long and greyish brown with dark brown markings in the centre of the forewings. They lay their small white eggs singly on the foliage or stems soon after the seedlings have been transplanted. The eggs hatch in just over a week. If the plants are young, the grubs burrow straight into the stems but if the plants are older, they enter the leaves and tunnel through the leaf stalks until they reach the stems. Full-grown caterpillars are about 12 millimetres long and greyish green or pink. Usually there are up to three caterpillars per plant, but sometimes there may be five or six. They are full-fed after about three weeks in summer and six weeks in winter. They pupate inside the stems, and the adults emerge ten to fifteen days later. Moths from the autumn crops emerge in July and August. Towards the end of October most caterpillars are full-fed, and another generation of moths starts to emerge in about early November. The moths start to lay when they are a week old and continue for three or four weeks. Each female may lay up to 400 eggs.

Injury The larvae burrow in the stems, starting 15 to 20 centimetres above ground and moving down to 2.5 centimetres or so below the surface. Infested plants wilt and die, usually when they are over 0.5 metre high and when the second and third trusses of fruit have set.

Dispersal The moths are capable of a short fluttering flight.

Control measures The remains of the autumn crop should be destroyed when harvesting is finished and not later than the beginning of July. Spraying with DDT 0.1 per cent, starting in the seedbed and continued at weekly intervals for up to two months after transplanting has been effective.

Egg-fruit caterpillar *Sceliodes cordalis*

Importance and Distribution This pest is widely distributed in New South Wales wherever eggplant is grown. It attacks tomatoes and capsicums, but is not an important pest on either of them.

Plants attacked Thornapple and some native species of *Solanum* are recorded as being infested, but eggplant is the most favoured host.

Description and Life History The adult moth has a wingspan of about 2.5 centimetres. The wing colour is yellowish brown with lighter transverse markings. Prominent golden marks on the tips of the forewings are edged with black. The wings are carried at an angle of about 45 degrees to the body, and the abdomen is bent up in a scorpion-like attitude. The moths are active at night and sluggish by day. The eggs are laid one or two to a fruit, usually on the calyx, and a moth may lay 100 in a single night. The eggs are creamy white, oval and dome-shaped. The newly-hatched larvae have colourless bodies and brown heads; they bore into the fruit, usually at the stem end under the shelter of the calyx lobes. The full-grown larva is nearly 2.5 centimetres long, and pink with a small brown head and a smooth glistening appearance. Some larvae bore into the

stem, causing the plant to wilt. After emerging from the fruit, the larva spins a whitish silken cocoon about 15 millimetres long which is pointed at one end and anchored by silken threads. The brown pupa develops inside the cocoon.

The life history has been studied in North Queensland (Davis, 1964) where, in spring and early summer, development from egg to adult takes three to five weeks.

Injury Damaged fruit usually breaks down and rots. When the grubs are small, injury is very difficult to see so infested fruit may be packed and the damage detected only when it arrives at the market.

Control measures Crop sanitation should be practised by removing susceptible weeds, and old plants where successive plantings are proposed. If required, weekly applications of carbaryl 0.1 per cent spray during the fruiting period should protect the eggplant satisfactorily.

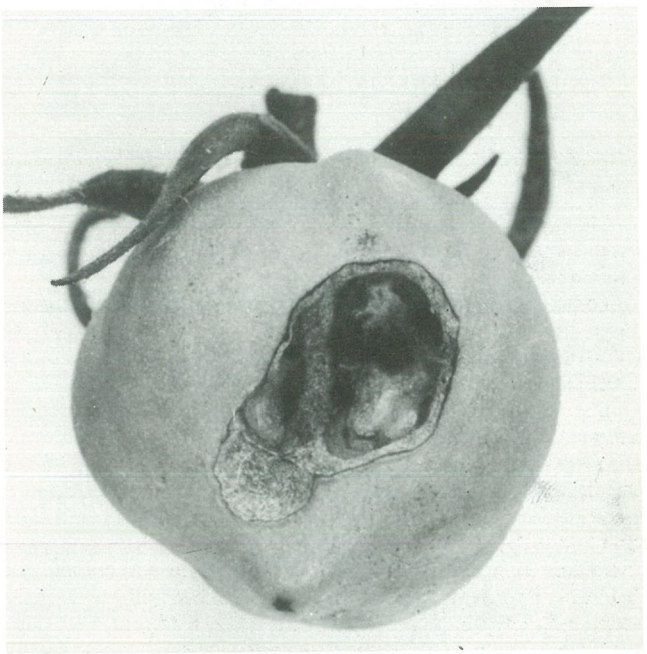
Eggplant stem opened to show damage by egg-fruit caterpillar.

Loopers *Chrysodeixis* spp.

These grubs may be troublesome in spring and autumn in field and glasshouse crops of tomatoes. Looper damage is unlikely to be severe except sometimes on a maturing crop in autumn when spraying for budworms may have ceased.

The pale green loopers are difficult to see as they feed on the undersides of leaves, but they can usually be detected from the pellets of excreta on the leaves below the ones on which they are feeding. The pellets are dark green and barrel-shaped. The loopers damage the plants by eating large rounded holes in the leaves and fruits. House sparrows eat the loopers, and will sometimes enter glasshouses to do so.

These pests are described in greater detail on page 223 under Bean Pests.



Looper damage to tomato fruit.

Cluster caterpillar *Spodoptera litura*

The common name for these grubs is derived from their behaviour when young; they cluster in groups while feeding on the undersurfaces of leaves. Later they disperse and feed singly on foliage or fruit. The mature caterpillars are 4 to 5 centimetres long, and usually brownish purple with a series of dark triangular markings on each side of the body.

Control measures If left alone, this pest can cause considerable damage, but it is normally controlled by the routine treatments required for other pests.

This pest is described in greater detail on page 251 under Cruciferous Pests.

Cutworms *Agrotis* spp.

If tomato seedlings are planted out on land that has recently carried a crop of weeds, heavy losses which require extensive replanting may occur in a few nights. The plants are cut off at ground level, and the top section is left lying on the soil. A search in the soil nearby will usually uncover a smooth dark or pinkish grub that curls itself into a circle.

Further details are given on page 221 under Bean Pests.

DIPTERA

Queensland fruit fly *Dacus tryoni*

This native fruit fly frequently infests tomatoes in home gardens, but it is rarely a pest of importance in commercial tomato crops grown in non-urban areas. Fruit fly maggots are commonly found in home-garden tomatoes and capsicums after mid-summer when the population of flies has built up rapidly in early stone fruits.

When the fruit are 'stung', maggot development proceeds normally, but firm fruit does not break down rapidly and quite large maggots may be found in fruits that seem to be sound. Once breakdown starts, however, it is usually rapid. A fruit fly 'sting' may be seen as a tiny pinhole, usually on the ripest section of the skin, and it often exudes a drop of juice.

Queensland fruit fly 'stings' (oviposition sites) in capsicum.

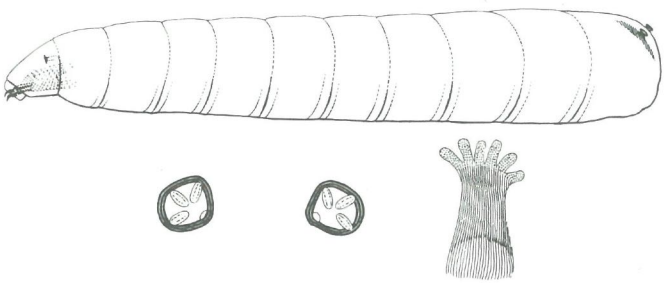
Control measures Fruit fly damage in home-garden tomatoes may be controlled by spraying with dimethoate 0.03 per cent when fly activity is first suspected, and at weekly intervals thereafter. All coloured fruit should be removed before spraying.

Details of the life history of Queensland fruit fly are given on page 33 under Citrus Pests.

Metallic-green tomato fly *Lamprolonchaea brouniana*

This fly attacks only fruit which has been injured or has split. This is likely to happen when fruit is allowed to hang on the bush until it is ripe. The adults are stoutly-built, bright green and about 6 millimetres long. The maggots are sometimes mistaken for the Queensland fruit fly larvae. Like true fruit fly maggots and their many relatives, these larvae are capable of skipping for a distance of several centimetres.

Infestation can be avoided by removing ripe and damaged fruit from the bushes and destroying it. Good control of other tomato pests reduces the occurrence of metallic-green tomato fly infestation.



Metallic-green tomato fly maggot – posterior spiracles at left, an anterior spiracle at right. (Length of maggot, when fully developed, about 6 mm)

Ferment flies *Drosophila* spp.

Tomatoes grown for processing remain on the bushes until they are fully coloured. Consequently some fruit will crack and, if the weather is unsuitable, cracking will be common. The damaged fruit attracts and breeds the ferment flies. They are small, soft-bodied, and about 3 millimetres long. The adults lay their eggs in any injured ripening fruit, and the white maggots grow up to 4 millimetres long and mature in a week. Waste fruit can quickly produce enormous swarms of flies which invade packing sheds and canneries, and may become a considerable nuisance.

Control measures Control is difficult. It depends on keeping the quantity of waste fruit to a minimum in the field and the cannery, and so reduce breeding. Damaged and infested fruit should be dumped in one place and sprayed frequently with maldison or diazinon.

These pests are discussed also on page 158 under Grape Pests.

COLEOPTERA

African black beetle *Heteronychus arator*

Importance and Distribution Newly-planted tomatoes in coastal districts are often attacked in spring or autumn by shining black beetles which chew the stems at ground level, causing sudden wilting and death. The beetles may be found in the adjacent soil. This beetle, a native of South Africa, was first seen in New South Wales near Newcastle in 1920 and is now found throughout the coastal area.

Conditions for Infestation African black beetles are favoured by dry weather in spring and early summer. If two relatively dry seasons follow each other, there is likely to be an enormous increase in the beetle population and in subsequent swarming. Abnormally high rainfall in the spring causes a decline in population.

Plants attacked They are serious pests of maize, market gardens and lawns, as well as many other plants. Tomato, cauliflower, cabbage, potato, rhubarb, dahlia, petunia, marigold and maize are particularly liable to attack (Wallace, 1945). Legumes are not attacked.

Description and Life History The beetles are 12 millimetres long, oval in outline and shining black. The eggs are greyish

African black beetle
Heteronychus arator

1 Eggs in soil; **2** larva; **3** pupa; **4** adult; **5** damaged plant stem; all enlarged about 3.5 times. **6** Eggs; **7** larva; **8** pupa; **9** beetles and damaged plants; all actual size.

white and ovoid at first, but later becoming spherical. The larvae are white curl grubs, and white or bluish white in colour with a brown head capsule; they assume a roughly semi-circular position when at rest. When fully developed they are about 2.5 centimetres long and 6 millimetres in diameter. The pupa is light brown and about 12 millimetres long.

African black beetles generally breed in mat-forming grasses like paspalum or kikuyu, and there is only one generation per year. They overwinter as adults, lying inactive in the soil. They resume feeding in the spring, lay eggs in the soil, and then die. The young larvae feed mainly on soil organic matter. More mature larvae attack grass roots. The time taken from egg-laying to the emergence of the new adults in January–February is about three months.

Injury Adults cause damage to tomatoes and other crops, and may be expected to attack when the plants are set out in land recently under pasture or close to pasture. The injured stems of the seedlings usually have a ragged teased-out look.

Dispersal The beetles either crawl readily into a crop from pasture or, not infrequently, take off in very large numbers on swarming flights. The latter occurs mainly in autumn, but they may also swarm in spring. For reasons that are not understood, large numbers of beetles leave the soil, crawl up on grass, fly some distance in groups, and then dig their way into the soil where they land. They are attracted to street lights and may attempt to burrow under the lights even though the surface may be impossibly hard.

Control measures If a young crop is attacked, DDT emulsion 0.1 per cent jetted into the soil at the base of each plant has proved to be effective.

Where infestation of a patch of land is suspected, it is recommended that it be treated with lindane-broken maize bait.

Vegetable weevil *Listroderes obliquus*

This insect attacks many vegetables, as well as weeds. On tomatoes, the adult weevils are usually the cause of damage although the grubs can also be harmful. The worst damage is likely to occur when the weevils emerge from the pupae in late winter. They chew the leaves at night and may leave only bare stalks. The weevils hide during the day under trash and clods; they feign death when uncovered. The larvae are pale green or creamy legless grubs that feed mainly at night and hide during the day. They may be found in the soil, and sometimes in the centres of shoots. Attack is most likely to occur when the land planted to tomatoes has been under weed growth, especially capeweed and marshmallow.

Control measures The land can be freed from weevils before the planting of tomatoes by boom-spraying the crop area with DDT or by using lindane-bran bait.

Further description and control measures will be found on page 253 under Cruciferous Pests.

Wireworms Elateridae
False wireworms Tenebrionidae

Tomatoes set out in land recently under pasture are sometimes attacked by these larvae. They chew the roots and sometimes bore up into the stems from just below the soil surface.

A more detailed discussion will be found on page 256 under Cruciferous Pests.

White fringed weevil *Graphognathus leucoloma*

Land recently under lucerne or clover, or even a heavy growth of mixed weeds, sometimes harbours numerous larvae of this beetle. When deprived of other food by the cultivation, they will attack newly-planted tomatoes. The thick-set, white or grey, legless, wrinkled grubs gouge furrows in the roots, and are usually found in the soil nearby. The slaty grey adult weevils, which are about 12 millimetres long, may invade the crop from adjoining weed growth or pasture, and strip the plants.

White fringed weevil and its control measures are discussed on page 281 under Potato Pests.

Leaf-eating ladybirds *Henosepilachna* spp.

Tomatoes growing near potato crops or weeds, such as thornapple, are sometimes attacked by overflow populations of both the larvae and adults of these insects. The larvae are oval, spiny, and brown and yellow. The beetles are orange with dark spots.

Control measures The attack is controlled by spraying the tomatoes with carbaryl 0.1 per cent.

Further details are given on page 262 under Cucurbit Pests.

THYSANOPTERA

Onion thrips *Thrips tabaci*

This insect does little direct damage to tomatoes, but it is believed to be the sole agent for transmitting the virus disease, spotted wilt. The brownish females are tiny and slender, 1.3 millimetres long, and have two pairs of delicate fringed wings and the males are somewhat smaller. They breed on weeds or garden plants and migrate to tomatoes, carrying the infection, especially when the weeds die off. Nasturtium, dahlia and

Iceland poppy are common hosts of the disease. Spotted wilt of tomatoes is usually most evident in late October and November.

Control measures Seedbeds and crops of tomatoes should be located as far as possible from weeds. Frequent spraying with DDT in the seedbed and in the crop reduced spotted wilt infection (Pasfield, 1952).

Further details on onion thrips are given on page 272 under Onion Pests.

HEMIPTERA

Vegetable jassid *Austroasca viridigrisea*

Importance and Distribution These leafhoppers are found in most parts of New South Wales, and may sometimes injure a tomato crop, especially if it is not irrigated. They are always most abundant and destructive in warm dry weather and are therefore more obvious in inland districts, but they can be important on the coast in dry spells in spring.

Conditions for Infestation The jassids are favoured by dry spells.

Plants attacked Many vegetable crops, including bean, carrot and potato, are susceptible to injury, as are some ornamentals. Broad-leafed weeds are commonly infested.

Description and Life History The adults are small insects, torpedo-shaped and green or greenish yellow, 4 millimetres long, with two pairs of wings. They have sucking mouthparts. The females lay their eggs within the tissues of the youngest parts of the plants, especially in the stems and leaf petioles. The young, which emerge from the eggs after about a week, resemble the adults but have no wings. They feed on the undersides of leaves and, when disturbed, move away with a characteristic sideways motion. After a series of moults over two or three weeks, the young jassids become adults. The incubation period for the eggs is ten to twelve days.

Injury Both young and adult jassids feed by puncturing leaves and sucking the juice. Punctures show up as small patches of whitened tissue. Numerous dots may run together until whole leaves are involved, which then curl at the edges and may die. Heavily infested plants become stunted and grey. Fruit may be attacked, showing faint whitish spots and small specks of jassid excreta scattered over the surface.

The related species common brown leafhopper, *Orosius argentatus* (Evans), is known to transmit big bud virus which is sometimes important. The insect transfers the infection from weeds or some ornamentals, such as gerbera and dahlia, to the tomatoes.

Dispersal When jassids are disturbed on a crop plant they fly out in small swarms, only to settle again on the same plant or on others close by. Even so, they do have the flying capacity to reach a new crop from old infested plants growing in the vicinity.

Control measures Well-watered crops of tomatoes seldom suffer direct damage by jassids. A good fall of rain will quickly remove an established infestation, and so will an irrigation watering. Wherever possible, likely sources of infestation in old crops or susceptible weeds should be treated or avoided.

Dimethoate 0.03 per cent spray is suitable for control.

Plant bugs of occasional importance on tomatoes

Several sap-sucking bugs – green vegetable bug, Rutherglen bug, harlequin bug, leptocoris bug, and green stink bug – may attack tomatoes at times, feeding on the surface of the fruit and creating pale dry areas of tissue.

GREEN VEGETABLE BUG, *Nezara viridula* This well-known shield-shaped green bug, about 12 millimetres long, was once a serious pest of tomatoes before the successful introduction of an egg parasite.

For further details see page 232 under Bean Pests.

RUTHERGLEN BUG, *Nysius vinitor* These small actively-flying grey-brown adults swarm on to tomatoes in certain seasons and quickly cause considerable damage.

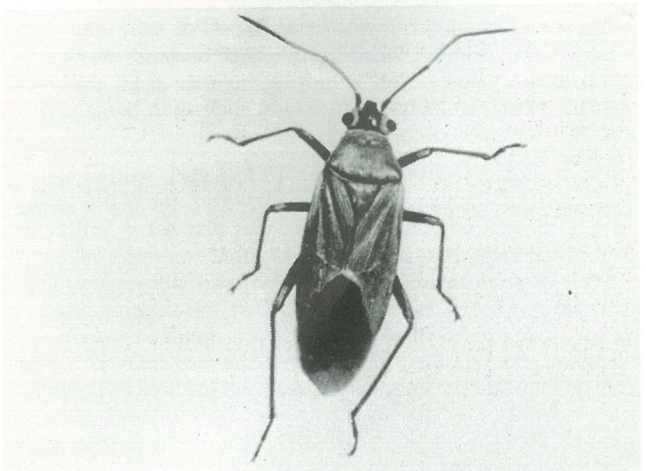
For further details see page 163 under Grape Pests.

HARLEQUIN BUG, *Dindymus versicolor* This insect is very occasionally destructive on tomatoes.

Further information on this insect will be found on page 233 under Bean Pests.

LEPTOCORIS BUG, *Leptocoris mitellata* This bug is widely distributed in New South Wales, mainly inland. It sometimes leaves its native hosts and attacks cultivated plants and fruit trees, as well as tomatoes and other vegetables. The adult is narrow-bodied, winged and about 12 millimetres long, and is generally reddish brown with lighter and darker markings. Underneath, the body is dull red with a dark green area in the middle of the abdomen. The legs and antennae are black.

For control measures refer to green vegetable bug on page 233 under Bean Pests.



Leptocoris bug. (Length about 12 mm)

GREEN STINK BUG, *Plautia affinis* This bug is only a very occasional pest on tomatoes.

Further information on this insect will be found on page 234 under Bean Pests.

Potato aphid *Macrosiphum euphorbiae*
Green peach aphid *Myzus persicae*

Importance and Distribution These two species of aphids may infest tomatoes wherever they are grown. Occasionally, they become sufficiently numerous to cause direct damage to tomatoes by sucking plant juices. Their greater significance is as vectors of virus diseases – yellow top, leaf shrivel and fern leaf.

Conditions for Infestation Cool dry weather favours the aphids so they are usually more troublesome in spring and autumn.

Plants attacked Both species of aphids breed on a wide variety of fruit trees, vegetables and other cultivated plants and weeds, such as peaches, nectarines, almonds, some varieties of plums, tomatoes, potatoes, peas, Iceland poppies, roses, sow thistles, docks, capeweed, black-berry nightshade (one of the hosts of yellow top virus) and many other plants.

Description and Life History Potato aphids are pale green to green and about 3 millimetres long, with rather long legs and slender prominent tubular processes or cornicles. Wingless or winged forms may be found on the same plant, clustering on the undersides of leaves and young shoots. They suck sap, producing much sticky colourless honeydew which may become infected with black sooty mould. They move sluggishly when disturbed. The adults reproduce by giving birth to living young, and there may be a very rapid increase in numbers.

Green peach aphids are smaller than potato aphids. Wingless adults are green to pale yellow or pink, while winged adults are green with darker markings. They are more active than potato aphids. During the warmer parts of the year they reproduce extremely fast by producing active young, not eggs, which grow into winged or wingless forms. In colder climates, they overwinter as eggs on peach and nectarine trees; these eggs hatch in the spring as winged forms which fly off to start colonies on weeds and vegetables, when the weather becomes warmer. In warm areas, green peach aphids sometimes feed and breed through winter in sheltered situations, such as in home gardens and well-sheltered orchards.

Injury Heavy infestations result in leaf curl, wilting and the production of abundant honeydew. However, the major importance of the aphids is as vectors of virus diseases – yellow top, leaf shrivel and fern leaf. The potato aphid transmits yellow top which can suppress the setting of fruit, partially or completely, depending upon the age of the plant at the time of infection. After the development of the first fruit, infection usually does not affect the yield significantly, but the fruit may be smaller than on uninfected plants. Infection in the seedbed or in the field after transplanting may arise from the flight of winged aphids from headland weeds infected with the virus. It is then spread from plant to plant mainly by the movement of the wingless forms that breed on the plants themselves (Braithwaite and Blake, 1961).

Control measures

NATURAL Many natural enemies – ladybirds, lacewing larvae, syrphid fly larvae and small wasp parasites – attack aphid colonies in the spring, and infestation can often be heavily reduced or eliminated by them. Weed growth should be prevented around seedbeds and crops.

APPLIED Control is aimed primarily at the prevention of virus diseases. Weekly spraying of the tomato crop, and the weeds around seedbeds and crops, from emergence with demeton-S-methyl 0.025 per cent (up to three weeks before harvest) or dimethoate 0.03 per cent (up to one week before harvest) should give satisfactory control.

More details of these aphids are given on page 131 under Peach and Nectarine Pests and on page 285 under Potato Pests.

Wingless potato aphid. (Length about 3 mm)

Green peach aphid. (Length 2.3 mm)

Cowpea aphid *Aphis craccivora*

Coastal tomato crops in New South Wales may be invaded in the spring by swarms of greenish black winged aphids, which may then produce colonies of the wingless form. The infestation can cause stunting of young plants. Many other crops may be infested as well as weeds.

This pest is described in greater detail on page 234 under Bean Pests.

Greenhouse whitefly *Trialeurodes vaporariorum*

These insects were once a pest of some importance, especially in glasshouses, until the introduction of a tiny wasp parasite, *Encarsia formosa*. More recently they have reappeared in increasing numbers. When numerous enough to cause injury, they appear as swarms of tiny (1.5 millimetres long) delicate four-winged insects that fly out from the plants when disturbed, and settle back again after a short time. They feed by sucking sap from the soft succulent leaves.

They are discussed in greater detail on page 235 under Bean Pests.

ORTHOPTERA

Mole crickets *Gryllotalpa* spp.

Tomatoes, and other vegetable or flower crops, in the early stages of growth in seedbeds or shortly after transplanting, are sometimes harmed by the tunnelling of mole crickets just below the soil surface. Seedlings may be dislodged or die as a result of the loosening of the soil. Sometimes the crickets chew succulent stems at ground level.

Mole crickets are velvety brown and about 3 centimetres long. They are thick-set and strong with forelegs that are well adapted for burrowing. They have wings and can fly strongly, being attracted to lights at night. Eggs are laid in the soil. The young resemble the adults, but are paler and have no wings.

If control is needed, success has been achieved by watering the seedbeds and around young transplants with chlordane 0.1 per cent.

Mole cricket. (Length about 3 cm)

Black field cricket *Teleogryllus commodus*

Tomato plants are sometimes attacked, shortly after planting out, by crickets that chew the foliage and stalks, and may destroy part of the crop. They are about 2.5 centimetres long and black or brown.

Field crickets are described in great detail on page 257 under Cruciferous Pests.

Wingless grasshopper *Phaulacridium vittatum*

Tomato crops in the tablelands are sometimes invaded in the late summer by swarms of these hoppers. They move in from nearby pasture land when their normal host plants have dried off. They can soon strip tomatoes of foliage, leaving only the skeletons of the plants.

Further details of the life history and suggestions for control are given on page 111 under Apple Pests and on page 275 under Pea Pests.

ARACHNIDA ACARINA

Tomato russet mite *Aculops lycopersici*

Importance and Distribution This pest is likely to cause injury in any tomato crop grown during summer anywhere in New South Wales. First recorded in Queensland in 1917, it was not proved to be in New South Wales until 1929, but there is good reason to believe that, by then, it had been troublesome for several years already (Morgan, 1935).

Conditions for Infestation Warm dry weather suits the mites which do most damage in summer and autumn.

Plants attacked Many solonaceous plants are attacked including potatoes, Cape gooseberry, wild gooseberry and nightshade.

Description and Life History Tomato russet mites are so small that they are virtually invisible without the aid of a lens. They are less than 0.25 millimetre long, torpedo-shaped and cream, with four legs at the front end of the body. They breed extremely rapidly to great numbers and can complete their life cycle in six days.

Injury The mites scrape the leaf surface and suck the juice. The leaves become silvery, then bronze on the undersurface and then curled. Stems and leaf stalks become brown and smooth. The leaves die progressively from the bottom of the plant, until only the top growth remains green. Blossoms may be shed and young fruits may gó rusty and hard. When the symptoms become obvious, the mites will have moved up to fresh green

tissue and will not be found on the bronzed area. Further bronzing will appear even after the mite population has been killed by spraying, the result of feeding before the treatment.

Dispersal Although the mites are wingless and have no effective means of locomotion over any but the smallest distance, they do spread remarkably quickly. This is probably by mechanical transfer on visiting insects, birds, or man and by wind transport on their own or on shrivelled leaves. They have the habit of standing perpendicular to the tissue surface and swaying in the air – probably an adaptation to wind transport.

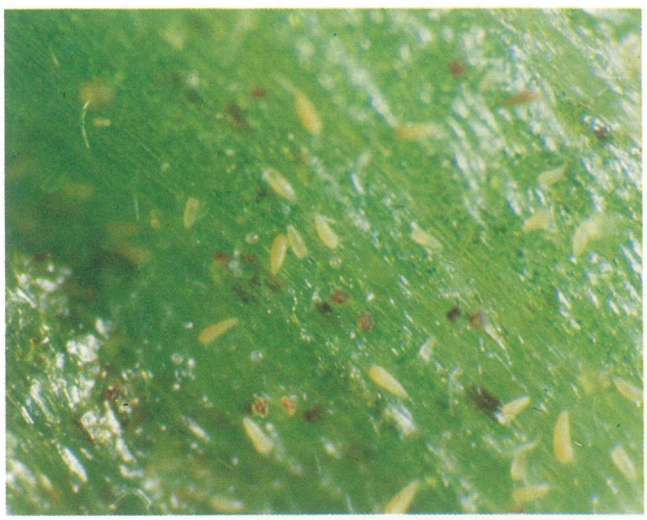
Control measures It is important to prevent infestation rather than waiting until the damage is obvious. Many different pesticides will kill the mites, but treatment should begin in the seedbed which should be remote from old tomato beds and host weeds.

Sprays of maldison 0.05 per cent or dimethoate 0.03 per cent applied at intervals of two or three weeks are recommended. Demeton-S-methyl 0.025 per cent is also effective but applications should cease three weeks before harvesting starts. Sulphur dusts and sprays are effective, the dust being especially useful for ground crops.

Tomato russet mite
Aculops lycopersici

1 Infested tomato plant showing drooping and withering of leaves, russeting and stunting of the fruit; actual size. **2** Mites on undersurface of leaf; enlarged seventy times.

Tomato plant damaged by tomato russet mite.



Tomato russet mites. (Length less than 0.25 mm)

Spider mites *Tetranychus* spp.

Occasional instances of spider mite infestation of tomatoes have been recorded, but these pests are not regarded as being significant in New South Wales. Eggplants are sometimes injured by spider mites.

Control measures Sulphur dusts or sprays, or the use of dicofol or dimethoate or demeton-S-methyl, give control.

Spider mites are discussed in detail on page 236 under Bean Pests.

References

Anon (1947). Weevils (*Curculionidae*) attacking growing peas. *Agricultural Gazette of New South Wales* **58**: 157.

Anon (1947). A silver beet stalk miner (*Haplomyza imitans*). *Agricultural Gazette of New South Wales* **58**: 158.

Anon (1951). *The Queensland Agricultural and Pastoral Handbook. Vol. III Insect Pests and Diseases of Plants*. Government Printer, Brisbane. 560pp.

Anon (1960). *Report of the Biology Branch, Department of Agriculture, Victoria.* Melbourne No. 1. 76pp.

Anon (1965). *CSIRO Division of Entomology Annual Report 1964–65.* Canberra, A.C.T. (p.72) 81pp.

Anon (1970). *Potato leafroll virus. Description of Plant Viruses No. 36.* Commonwealth Mycological Institute and the Association of Applied Biologists. October 1970.

Anon (1970). *CSIRO Division of Entomology Annual Report 1969–70.* Canberra, A.C.T. (p.45) 100pp.

Ballantyne, B. and Pulver, R. J. (1972). Reaction of pea varieties to top yellows disease in New South Wales. *Agricultural Gazette of New South Wales* **83**: 26–8.

Braithwaite, B. M. and Blake, C. D. (1961). Potato aphids and tomato yellow top virus. *Agricultural Gazette of New South Wales* **72**: 627–9, 660.

Common, I. F. B. (1953). The Australian species of *Heliothis* (Lepidoptera:Noctuidae) and their pest status. *Australian Journal of Zoology* **1**: 319–44.

Davis, J. J. (1964). The egg fruit caterpillar. *Queensland Agricultural Journal* **90**: 76–8.

Evans, J. W. (1943). *Insect Pests and Their Control.* Department of Agriculture, Tasmania. Government Printer, Tasmania. 179pp.

Froggatt, W. W. (1899). Entomological notes for 1898. *Agricultural Gazette of New South Wales* **10**: 873–9.

Froggatt, W. W. (1916). The tomato and bean bug. *Agricultural Gazette of New South Wales* **27**: 649–50.

Fuller, C. (1896). The small cabbage-moth (*Plutella cruciferarum* Zeller). *Agricultural Gazette of New South Wales* **7**: 444–9.

Gellatley, J. G. (1966). The bean fly, *Melanagromyza phaseoli. Agricultural Gazette of New South Wales* **77**: 425–7.

Greenup, L. R. (1967). The blue oat mite *Penthaleus major* (Dugès) (Acarina:Eupodidae). *Agricultural Gazette of New South Wales* **78**: 410–11.

Grylls, N. E. (1972). Aphid infestation and virus infection of peas and beans on the Central Tablelands of New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandry* **12**: 668–74.

Harries, F. H. (1966). Reproduction and mortality of the two-spotted mite on fruit seedlings treated with chemicals. *Journal of Economic Entomology* **59**: 501–05.

Hely, P. C. (1946). Control of *Thrips tabaci* on onions. *Agricultural Gazette of New South Wales* **57**: 467–71.

Hely, P. C. (1948). Bean fly control. *Agricultural Gazette of New South Wales* **59**: 419–20.

Hely, P. C. (1955). Further experiments in control of French bean fly. *Agricultural Gazette of New South Wales* **66**: 92–3.

Hogan, T. W. (1966). Physiological differences between races of *Teleogryllus commodus* (Walker) (Orthoptera:Gryllidae) related to a proposed genetic approach to control. *Australian Journal of Zoology* **14**: 245–51.

Hooper, G. H. S. (1957). The potato broad mite. *Queensland Agricultural Journal* **83**: 56–8.

Hughes, R. D., Casimir, M., O'Loughlin, G. T. and Martyn, E. J. (1964). A survey of aphids flying over Eastern Australia in 1961. *Australian Journal of Zoology* **12**: 174–200.

Johnson, J. C. (1956). Pod twist: a previously unrecorded bacterial disease of French bean (*Phaseolus vulgaris* L.) *Queensland Journal of Agricultural Science* **13**: 127–58.

Kleinschmidt, R. P. (1970). Studies of some Agromyzidae in Queensland. *Queensland Journal of Agricultural and Animal Sciences* **27**: 341–84.

Lloyd, N. C. (1943). The potato moth. Experiments on its control. *Agricultural Gazette of New South Wales* **54**: 323–27, 337, 417–21.

Lloyd, N. C. (1944). The potato moth. Experiments on its control. *Agricultural Gazette of New South Wales* **55**: 107–10, 126.

Lloyd, N. C. (1950). Hilling to control potato moth in tableland potato crops. *Agricultural Gazette of New South Wales* **61**: 409–14.

McCarthy, T. (1922). The seed bean midge (*Camptocladius macleayi* Skuse.). *Agricultural Gazette of New South Wales* **33**: 733–7.

May, A. W. S. (1963). An investigation of fruit flies (fam. Trypetidae) in Queensland. 1. Introduction, species, pest status and distribution. *Queensland Journal of Agricultural Science* **20**: 1–82.

Metcalf, C. L., Flint, W. P. and Metcalf, R. L. (1962). *Destructive and Useful Insects. Their Habits and Control.* McGraw-Hill Book Co., Inc. New York. 1087pp.

Morgan, W. L. (1935). The tomato mite (*Phyllocoptes lycopersici*, Tryon.). *Agricultural Gazette of New South Wales* **46**: 683–4.

Morgan, W. L. (1938a). For bean fly control use white oil-nicotine sulphate mixture. *Agricultural Gazette of New South Wales* **49**: 22–4.

Morgan, W. L. (1938b). Control of bean fly. *Agricultural Gazette of New South Wales* **49**: 501–03.

Noble, N. S. (1937). An egg parasite of the green vegetable bug. *Agricultural Gazette of New South Wales* **48**: 337–41.

Noble, N. S. (1938). The greenhouse white fly. Control by the parasite *Encarsia formosa*. *Agricultural Gazette of New South Wales* **49**: 253–5, 287.

Pasfield, G. (1952). Tomato spotted wilt. Control with DDT sprays. *Agricultural Gazette of New South Wales* **63**: 138–44.

Passlow, T. and Rigby, L. W. (1967). Potato pests of south Queensland. *Queensland Agricultural Journal* **93**: 641–5.

Sherman, M. and Mitchell, W. C. (1953). Control of sweet potato weevil and borer in Hawaii. *Journal of Economic Entomology* **46**: 389–93.

van Regteren Altena, C. O. and Smith, B. J. (1975). Notes on introduced slugs of the families Limacidae and Milacidae in Australia, with two new records. *Journal of the Malacological Society of Australia* **3**: 63–80.

Vevers Steele, H. (1935). *Thrips investigations: Some common Thysanoptera in Australia.* Council for Scientific and Industrial Research Pamphlet No. 54.

Wallace, C. R. (1940). On the occurrence of the weevil *Naupactus leucoloma* Boh. in Australia. *Journal of the Australian Institute of Agricultural Science* **6**: 209–11.

Wallace, C. R. (1945). The black beetle (*Heteronychus sanctae-helenae*) as it affects coastal vegetable growers and horticulturists. *Agricultural Gazette of New South Wales* **56**: 339–48.

Wilson, F. (1960). *A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea.* Technical Communication No. 1, Commonwealth Institute of Biological Control, Ottawa, Canada. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England. 102pp.

Yathom, S. (1968). Phenology of the tuber moth, *Gnorimoschema operculella* Zell., in Israel in the spring. *Israel Journal of Agricultural Research* **18**: 89–90.

Zeck, E. H. (1933). Investigations on the green vegetable bug (*Nezara viridula* Linn). *Agricultural Gazette of New South Wales* **44**: 591–4, 675–82.

Index

Acacia spp.
  hosts, of *Cryptophasa melanostigma* 141
    of *Cryptophlebia ombrodelta* 183
    of scale insects 65
Acanthoscelides obtectus **229–30**
acaricides
  against *Tetranychus urticae*, on apples 114
  synthetic, use on citrus 20
  toxicity 6
acephate
  against *Heliothis* spp., on tomatoes 29?
  crop withholding periods 8
Acrocercops chionosema **182**
Acts of Parliament (N.S.W.)
  Pesticides 1978 viii,2,10
  Plant Diseases 1924 (amended) 34,52,95,172,175,177
  Poisons 1966 10
  Public Health 1902 10
  Pure Food 1908 (amended) 10
Aculops lycopersici **299–300**
Aculus cornutus **138**
African black beetle
  on bananas 175
  on beetroot 241
  on crucifers 255
  on grapevines 158–9
  on passionfruit 188
  on potatoes 284
  on rhubarb 241
  on strawberries 209
  on tomatoes **295–6**
Agrius convolvuli **287–8**
Agromyzidae 187,253
Agrotis spp. 157,208,**221–2**,241,244, 253,260,267,271,274,281,288,294
almond trees
  cultivation, N.S.W. 139
  hosts, of *Myzus persicae* 131
  pests (listed) 139
  pests, *Brachycaudus persicae* 139
    Bryobia rubrioculus 140
    Comstockaspis perniciosus 139
    Cydia molesta 139
    Myzus persicae 139
    Tetranychus urticae 140
almonds
  pests (listed) 139
  pests, *Dysdercus sidae* 139
    Scutiphora pedicellata 139
Alocasia macrorrhiza 176
Amblypelta nitida 136,144,181,183–4
Amblyseius womersleyi 211
aminocarb
  crop withholding periods 8
  toxicity 6
Anicetus communis 47,59
Anoplognathus spp. 142
ants
  interactions with scale insects 31,63,64
  on citrus **31**
  parasites of *Bruchophagus fellis* 30
  vectors of scale insects 46
Aonidiella aurantii **47–52**,199
Aonidiella citrina **52**
Apanteles spp. 250,251,280
Aphelinus mali 106
Aphidius sp. 177
aphids
  on citrus 68
Aphis citricola 107
Aphis craccivora **234–5**,247,265,275,299
Aphis gossypii **265**
Aphytis spp. **46–7**,50–1,52,53,56,185
apple crops
  distribution, N.S.W. 91
apple dimpling bug **110**
apple fruits
  hosts, of *Dirioxa pornia* 35
  pests (listed) 91–2
  pests, *Campylomma livida* **110**
    Cydia pomonella **92–6**
    Dacus tryoni 100
    Epiphyas postvittana **96–9**
    Phaulacridium vittatum **111–2**
    Sitophilus spp. 102
  withholding periods after sprays 8
apple leafhopper **111**
  on plums and prunes 144
apple moths
  light-brown, on apples **96–9**
    on apricots 145
    on carrots 244
    on citrus 25–6
    on grapevines 157
    on peaches and nectarines 128
    on pears 117
    on plums and prunes 141
    on strawberries 208
  painted, on apples 99
apple mussel scale **110**
apple root weevil **101**
apple trees
  growth and development 91
  hosts, of *Aphis craccivora* 235
    of *Leptopius squalidus* 39
    of *Otiorhynchus cribricollis* 40
  integrated pest control **95–6**
  pests (listed) 91–2
  pests, *Aphis citricola* 107
    Bryobia rubrioculus 114–5
    Comstockaspis perniciosus **107–9**
    Epiphyas postvittana **96–9**
    Eriosoma lanigerum 104–7
    Geloptera porosa 102
    Heliothis spp. 99
    Lepidosaphes ulmi **110**
    Leptopius squalidus 100–101
    Panonychus ulmi **115–6**
    Parlatoria pittospori **109–10**
    Perperus spp. **101**
    Phaulacridium vittatum **111–2**
    Teia anartoides **99–100**
    Tetranychus urticae 112–4
    Thrips imaginis **102–4**
    Typhlocyba froggatti **111**
  rootstocks, woolly aphid resistance 106
apple weevil
  on citrus **40**
  on peaches and nectarines 130
apricot crops
  distribution, N.S.W. 145
apricot fruits
  pests (listed) 145
  pests, *Carpophilus* spp. 146
    Epiphyas postvittana 145
    Eulecanium pruinosum 147
    Nysius vinitor 147
apricot trees
  pests (listed) 145
  pests, *Comstockaspis perniciosus* 147
    Doratifera spp. 145–6
    Epiphyas postvittana 145
    Eulecanium pruinosum 147
    Xyleborus saxeseni 146
Argentine ant 31,63
Aricerus eichoffi **196**
armoured scales **44–5**,47–56
armyworms 288
Aspidiotophagus sp. 55
Aspidiotus nerii 200
assassin bug
  predator, of *Biprorulus bibax* 71
    of *Musgraveia sulciventris* 73
Asynonychus cervinus **36–7**,187,210,229,242,264
attractants
  of *Cydia pomonella* 96
  of *Dacus tryoni* 35
  Aulacaspis rosae **206**
  Aulacophora hilaris **261–2**
  Austracris guttulosa 76,165
  Australian citrus whitefly 68
Australian plague locust 76
Australian round lime 71
Austroasca australica **197**
Austroasca viridigrisea 234,247,285,**297**
Austropeplus sp. **74**
avocado fruits
  pests (listed) 179
  pests, *Amblypelta nitida* 181
    Chrysomphalus dictyospermi 181
    Dacus tryoni 180
    Rhyparida sp. 180
avocado trees
  cultivation, N.S.W. 179
  hosts, of *Ceroplastes rubens* 60
  pests (listed) 179
  pests, *Chrysomphalus dictyospermi* 181
    Fiorinia fioriniae 181
    flea beetles 180
    Hemiberlesia lataniae 180
    Monolepta australis 180
    Oiketicus elongatus **179**
    Oxycarenus arctatus 181
    Rhyparida sp. 180
azinphos-ethyl
  against *Graphognathus leucoloma* 282
    Phthorimaea operculella 280,292
  crop withholding periods 8
  toxicity 6
azinphos-methyl
  against *Asynonychus cervinus* 37
    Cydia molesta 127
    Cydia pomonella 95,117
    Epiphyas postvittana 26,99,128,145,244
    Isotenes miserana 25
    Orthorhinus cylindrirostris 159
    Otiorhynchus cribricollis 40
    Phycomorpha prasinochroa 194
    Prays parilis 27
    Rhinaria perdix 209
    snails 83
    Typhlocyba froggatti 111
  crop withholding periods 8
  toxicity 6
azocyclotrin
  against *Tetranychus urticae* 114

Bacillus thuringiensis (as insecticide)
  crop withholding periods 8
bait sprays
  against *Dacus tryoni* 34,100,118,129,157,173,180,187,199
baits
  for *Agrotis* spp. 222,253,281
    Heteronychus arator 209, 255, 284
    Listroderes obliquus 255,296
    slugs and snails 82,168,212,239,248,277
    Teleogryllus commodus 211,258
    Tiracola plagiata 173
banana aphid **177**
banana crops
  distribution, N.S.W. 172
  quarantine protection, N.S.W. 172,175,177
banana fruit caterpillar **173**
banana fruits
  pests (listed) 172–3
  pests, *Chaetanaphothrips signipennis* **176**
    Dacus tryoni 173
    Hemiberlesia lataniae **177**
    Hercinothrips bicinctus 176–7
    Tiracola plagiata **173**
banana plants
  cultivation, N.S.W. 172
  pests (listed) 172–3
  pests, *Cosmopolites sordidus* **174–5**
    Heteronychus arator 175
    Monolepta australis 175
    Pentalonia nigronervosa 177
    Tetranychus lambi **178**
    Tiracola plagiata **173**
banana rust thrips **176**
banana silvering thrips **176–7**
banana spider mite
  see strawberry spider mite
banana weevil borer **174–5**
Banksia spp.
  hosts, of *Cryptophasa melanostigma* 141
Batachedra sp.
  predator, of *Aonidiella aurantii* 50
    of *Aulacaspis rosae* 206
    of *Unaspis citri* 55
Bathurst burr
  host, of *Aonidiella aurantii* 48
Bauhinia spp.
  hosts, of *Cryptophlebia ombrodelta* 183
bean blossom thrips **230–1**
bean crops
  cultivation, N.S.W. 218
  distribution, N.S.W. 218
bean fly **226–7**
bean plants
  pests (listed) 218–9
  pests, *Agrotis* spp. **221–3**
    Aphis craccivora **234–5**
    Asynonychus cervinus 229
    Austroasca viridigrisea 234
    Brevipalpus spp. 238
    Chrysodeixis spp. **223–4**
    Creontiades dilutus 231
    Delia platura **228**
    Deroceras spp. 239
    Dindymus versicolor **233–4**
    Diphucephala sp. 229
    Graphognathus leucoloma 228–9
    Helix aspersa 239
    Henosepilachna spp. 229
    Maruca testulalis 224–5
    Milax gagates 239
    Nysius vinitor 233
    Ophiomyia phaseoli 226–7
    Scolypopa australis 234

Scutigerella immaculata 238
Smittia macleayi **228**
Smynthurodes betae **235**
Taeniothrips nigricornis **230–1**
Tetranychus spp. **236–8**
Thrips tabaci 231
Trialeurodes vaporariorum 235
Zizina labradus **225–6**
bean pod borer **224–5**
bean root aphid **235**
bean spider mite *see* spider mites
bean weevil **229–30**
bean yellow mosaic virus 235
beans
pests (listed) 218–9
pests, *Acanthoscelides obtectus* **229–30**
Heliothis spp. **219–21**
Nezara viridula **232–3**
Plautia affinis 234
Riptortus serripes 233
Bedellia somnulentella **289**
bees
antagonists of *Gascardia destructor* 59
toxicity of insecticides to 8
beet leaf-miner 241
beet webworm **240–1**
beetles
predators, of *Agrotis* spp. 222
of *Cosmopolites sordidus* 175
of *Cydia pomonella* 95
beetroot
cultivation, N.S.W. 239
pests (listed) 239–40
pests, *Agrotis* spp. 241
Halotydeus destructor 243
Hymenia recurvalis **240–1**
Liriomyza chenopodii 241
Listroderes obliquus 242
Penthaleus major 243
Teleogryllus commodus 242
Tetranychus spp. 243
berry fruit plants
cultivation, N.S.W. 204
pests (listed) 204
pests, *Aulacaspis rosae* **206**
Philomastix macleaii **205**
berry fruits
pests (listed) 204
pests, *Thrips imaginis* 205
binapacryl
against *Tetranychus urticae* 138,144
crop withholding periods 8
toxicity 6
Biprorulus bibax **70–1**
birds
predators, of *Agrotis* spp. 222
of bronze orange bug 73
of *Caedicia* spp. 76,138
of citrus aphids 69
of *Gascardia destructor* 59
of *Phalaenoides glycinae* 156
of snails 82,83
toxicity of insecticides to 8
vectors of scale insects 46
black cicada
on grapevines **165**
black currants *see* bush fruits
black citrus aphid *see* citrus aphids
black field cricket
on beets 242
on crucifers **257–8**
on strawberries 211
on tomatoes 299
black-keeled slug *see* slugs
black peach aphid *see* peach aphid
black scale
on citrus **61–3**
on olives 198
on passionfruit 189–90
blackberry plants
hosts, of *Caedicia* spp. 75
blackthorn plants
hosts, of *Gascardia destructor* 57
Blaesoxipha pachytyli 112
blue oat mite
on beets 243
on crucifers 259
on cucurbits 266
on lettuce 270
on peas **275–7**
Bordeaux mixture
against melanose fungus 42
slugs and snails 83,168,212,239,248,277
compatibility with insecticides 53–4
Bostrychopsis jesuita **196**
boxthorn plants
hosts, of *Ceroplastes sinensis* 60
boysenberries *see* berry fruits
Brachycaudus persicae **133–5**,139,143
bramble sawfly
on berries **205**
Brevicoryne brassicae **256–7**
Brevipalpus lewisi **167–8**
Brevipalpus phoenicis 190
Brevipalpus spp. **81**,211,238
broad mite
on citrus **79–80**
on cucurbits 266
on grapevines 168
on potatoes 286
on rhubarb 242–3
on silver beet 242–3
broccoli *see* cruciferous vegetables
bromopropylate
against *Panonychus ulmi* 116
Tetranychus urticae 114,138,144
crop withholding periods 8
toxicity 6
bronze orange bug
on citrus **71–4**
brown citrus rust mite
see citrus rust mites
brown leaf-eating beetle
on avocados 180
brown slug *see* slugs
Bruchophagus fellis **29–31**
Bryobia cristata 266
bryobia mite
on almonds 140
on apples **114–5**
on peaches and nectarines 138
on pears 119
on plums and prunes 144
Bryobia rubrioculus **114–5**,119,138,140,144
budworms
on apples 99
on beans **219–21**
on citrus 28
on crucifers 253
on lettuce 267
on peaches and nectarines 128
on peas 274
on strawberries 207
on tomatoes 291
bulb mite
on onions **273**
bunch mite
on grapevines **167–8**
Bursaria spinosum
host, of *Gascardia destructor* 57
bush fruits
cultivation, N.S.W. 204
pests (listed) 204
pests, *Synanthedon tipuliformis* **204–5**
Thrips imaginis 205
cabbage aphid
on crucifers **256–7**
cabbage-centre grub
on crucifers **252**
cabbage moth
on crucifers **250–1**
cabbage white butterfly
on crucifers **249–50**
on silver beet 241
cabbages *see* cruciferous vegetables
Caedicia olivacea 76
Caedicia simplex **75–6**,**137–8**,144
Caedicia strenua **75–6**,**137–8**
Calepitrimerus vitis **167**
California red scale
on citrus **47–52**
on olives 199
Caliroa cerasi 117–8,142,**148–9**
Camellia spp.
hosts, of *Coccus hesperidum* 64
Campylomma livida **110**
capeweed
hosts, of *Epiphyas postvittana* 25
of *Myzus persicae* 131
of *Perperus lateralis* 40
of *Thrips imaginis* 103
Capnodiales *see* sooty mould
capsicums
cultivation, N.S.W. 290
pests (listed) 291
pests, *Dacus tryoni* 294
Sceliodes cordalis **292–3**
carbamate insecticides 5
against *Gascardia destructor* 59
poisoning symptoms 7
use on citrus 20
carbaryl
against *Anoplognathus* spp. 142
Aricerus eichoffi 196
Asynonychus cervinus 37,187,210,229,242
Aulacophora hilaris 262
Austroasca australica 197
cicadas 137
Comstockaspis perniciosus 109,135
Cryptophlebia ombrodelta 183
Cydia molesta 127
Cydia pomonella 95,117
Diphucephala sp. 158
Doratifera spp. 146
Epiphyas postvittana 26,99,128,141,145,157,244
Eutinophaea bicristata 39
flea beetles 180
Forficula auricularia 264
Gascardia destructor 59
Geloptera porosa 102
Halticinae 284,290
hawk moths 288
Henosepilachna spp. 229,264,283,296
Hyalarcta huebneri 27,157
Hymenia recurvalis 241
Isotenes miserana 25
Maleuterpes spinipes 38
Mandalotus sp. 188
Monolepta australis 43,188,264
Monolepta divisa 158
Mythimna convecta 288
Neodrepta luteotactella 183
Nezara viridula 136
Orthorhinus cylindrirostris 159
Papilio spp. 24
Parasaissetia nigra 197
Phalaenoides glycinae 155
Perperus lateralis 40
Phycomorpha prasinochroa 194
Phyllotreta nemorum 256
Phytoptus pyri 119
Poneridia semipullata 195
Porthesia paradoxa 128, 157
Rhinaria perdix 209
Saissetia oleae 63,189
Sceliodes cordalis 293
Teia anartoides 100
Tiracola plagiata 173
crop withholding periods 8
toxicity 6
carbon bisulphide
fumigant for bean seeds 230
carbophenothion
crop withholding periods 8
toxicity 6
Carphurus sp. 95
Carpophilus spp. **129–30**,146
carrot aphid **246**
carrot motley dwarf virus 246
carrots
cultivation, N.S.W. 243
pests (listed) 244
pests, *Agrotis* spp. 244
Aphis craccivora 247
Austroasca viridigrisea 247
Cavariella aegopodii **246**
Creontiades dilutus 247
Deroceras spp. 248
Dysaphis foeniculus 247
Elateridae 247
Epiphyas postvittana 244
Graphognathus leucoloma 245
Listroderes obliquus 245–6
Merophyas divulsana 244
Nysius vinitor 247
Rhizoecus falcifer 247
Tenebrionidae 246
Tetranychus spp. 247
case moths
leaf c.m., *see* leaf case moth
Saunders' c.m., *see* Saunders' case moth
Cassia spp.
hosts, of *Cryptophlebia ombrodelta* 183
Catoblemma dubia
predator, of *Parthenolecanium persicae* 162
of scale insects 31,60,63,64
cauliflowers *see* cruciferous vegetables
Cavariella aegopodii **246**
celery
cultivation, N.S.W. 243
pests (listed) 244
pests, *Austroasca viridigrisea* 247
Graphognathus leucoloma 245
Listroderes obliquus 245–6
Melanagromyza apii **245**
celery fly **245**
centipedes
on beans 238
Ceranisus sp.
parasite of *Heliothrips haemorrhoidalis* 43
Ceratitis capitata **35–6**
cereal crops
hosts of *Agrotis* spp. 221
Cermatulus nasalis 195
Ceroplastes rubens **60**
Ceroplastes sinensis **60–1**
Chaetanaphothrips orchidii **44**
Chaetanaphothrips signipennis **176**
Chaetosiphon fragaefolii 210
Chauliognathus lugubris 149
Chenopodium album see fat hen
cherry aphid **149–51**
cherry crops
distribution, N.S.W. 147
cherry fruits
pests (listed) 147–8

pests, *Chauliognathus lugubris* 149
cherry trees
cultivation, N.S.W. 147
pests (listed) 147–8
pests, *Caliroa cerasi* **148**
Myzus persicae **149–51**
Chinese wax scale
on citrus **60–1**
chives *see* onions
chlordane
against *Orthorhinus cylindrirostris* 37
termites 286
toxicity 6
chlorfenvinphos
crop withholding periods 8
toxicity 6
chlorpyrifos-methyl
against *Cosmopolites sordidus* 175
Heliothis spp. 292
crop withholding periods 8
toxicity 6
choko plants
hosts, of *Hercinothrips bicinctus* 176
chokos *see* cucurbit vegetables
Chortoicetes terminifera 76
Christmas beetle
on pineapples 185
on plums and prunes 142
Chrysodeixis argentifera **223–4**
Chrysodeixis eriosoma **223–4**
Chrysodeixis spp.
207,**223–4**,241,252,267,281,293
Chrysomphalus aonidum **56**
Chrysomphalus dictyospermi 181
Chrysopa spp.
predators, of *Pseudococcus longispinus* 162
of scale insects 49,63
cicada
black, *see* black cicada
on peaches and nectarines 137
Cicadellidae 75
cineraria leaf-miner **267–8**
circular black scale
on citrus **56**
citricola scale
on citrus **64–5**
citrophilous mealybug 66,67
citrus aphid **68–70**
on macadamia 184
citrus blossom bug **74**
citrus branch borer 41,**42**
citrus bud mite **76–7**
citrus butterflies
large **23–4**
small **23–4**
citrus crops
distribution, N.S.W. 14
insecticides uses in 16–21
citrus fruits
importance of pests, factors in 15
pests (listed) 22–3
pests, *Biprorulus bibax* **70–1**
Ceratitis capitata **35–6**
Chaetanaphothrips orchidii **44**
Coccus hesperidum **64**
Coccus pseudomagnoliarum 64–5
Dacus tryoni **31–5**
Dirioxa pornia **35**
Epiphyas postvittana 25–6
fruit-sucking moths **28–9**
Heliothis spp. 28
Heliothrips haemorrhoidalis **43**
Icerya purchasi **65–6**
Isotenes miserana **24–5**
Othreis spp. **28–9**
Planococcus citri 66,67
Polyphagotarsonemus latus **79–80**
Pseudococcus spp. 66,67
rust mites **78–9**
Saissetia oleae **61–3**
withholding period after sprays 8
citrus gall wasp **29–31**
citrus katydid *see* katydids
citrus leaf-eating weevil **39**
citrus leaf-miner **28**
citrus longicorn 41,**42**
citrus mealybug 66,67
citrus red mite **80–1**
citrus rust mite **78–9**
citrus rust thrips **44**
citrus trees
growth and development 15
hosts, of *Caedicia* spp. 137
of *Chaetanaphothrips signipennis* 176
importance of pests, factors in 15
injury by petroleum oils 18
pests (listed) 22–3
pests, *Aonidiella aurantii* **47–52**
Asynonychus cervinus 36–7
Austropeplus sp. 74
Brucophagus fellis 29–31
Caedicia spp. **75–6**
Ceroplastes rubens **60**
Ceroplastes sinensis **60–1**
Chrysomphalus aonidum 56
Coccus hesperidum **64**
Coccus pseudomagnoliarum **64–5**
Eriophyes sheldoni **76–7**
Eutinophaea bicristata 39
Gascardia destructor 56–9
grasshoppers 76
Heliothrips haemorrhoidalis 43
Helix aspersa **82–3**
Hyalarcta huebneri 26–7
Icerya purchasi **65–6**
Ixeuticus longinquus **81**
leafhoppers 75
Lepidosaphes beckii 52
Leptopius squalidus 39
locusts 76
longicorn borers 41–2
Maleuterpes spinipes 38–9
Mictis profana **74**
Monolepta australis 43
Musgraveia sulciventris **71–4**
Nysius vinitor 74
Orchamoplatus citri **68**
Orthorhinus cylindrirostris 37
Otiorhynchus cribricollis 40
Panonychus citri 80
Papilio spp. **23–4**
Perperus lateralis 40
Phyllocnistis citrella 28
Planococcus citri 66, 67
Prays parilis 27
Pseudococcus spp. 66, 67
Saissetia oleae **61–3**
scale insects **44–66**
Scolypopa australis 75
Siphanta acuta 74
Thrips imaginis 44
Torbia perficita 76
Toxoptera spp. **68–70**
Cleridae
parasites of longicorn borers 42
Clivina biplagiata 255
clover blue butterfly
see grass blue butterfly
clover mite
on cucurbits 266
cluster caterpillar
on beets 241
on crucifers **251–2**
on lettuce 267
on onions 271
on rhubarb 241
on strawberries 208
on tomatoes 293
Coccidae *see* soft scales
Coccinella repanda 69,133,135,150
Coccophagus spp.
parasites of scale insects 63,64
Coccus hesperidum **64**,190
Coccus pseudomagnoliarum **64–5**
codling moth
on apples **92–6**
on pears 117
on plums and prunes 142
on quinces 120
Coelophora inaequalis 69
Coleoptera *see* beetles
Colomerus vitis **165–7**
common spotted ladybird
see Harmonia conformis
Comperiella bifasciata
parasite of scale insects 47,50–51,52
Comstockaspis perniciosus **107–9**,118,135,139,143,147
convolvulus hawk moth *see* hawk moths
coon bug
on avocados 181
on grapevines 164–5
on peaches **136**
Copidosoma koehleri 280
copper oxychloride
against *Acanthoscelides obtectus* 230
longicorn beetles 42
Coscinoptycha improbana 197
Cosmopolites sordidus **174–5**
cotton aphid *see* melon aphid
cotton plants
hosts of *Chrysodeixis* spp. 223
cottony cushion scale
on citrus **65–6**
cowpea aphid
on cucurbits 265
on beans **234–5**
on carrots 247
on peas 275
on tomatoes 299
crab apples
hosts of *Cydia pomonella* 92
Creontiades dilutus **137**,189,231,247,265,286
Creontiades sp. 242
cruciferous vegetables
cultivation, N.S.W. 248
pests (listed) 248
pests, Agromyzidae 253
Agrotis spp. 253
Brevicoryne brassicae **256–7**
Chrysodeixis spp. 252
Clivina biplagiata 255
Delia platura 253
Desiantha diversipes 255
Dindymus versicolor 257
Elateridae 256
Gastrimargus musicus 258
Graphognathus leucoloma 255
Halotydeus destructor 259
Heliothis spp. 253
Hellula hydralis **252**
Heteronychus arator 255
Listroderes obliquus **253–5**
Myzus persicae 257
Nezara viridula 257
Nysius vinitor 257
Pentatheleus major 259
Phaulacridium vittatum 258
Phyllotreta nemorum 256
Pieris rapae **249–50**
Plutella xylostella **250–1**
Spodoptera litura **251–2**
Teleogryllus commodus **257–8**
Tenebrionidae 256
Thrips tabaci 256
withholding periods after sprays 8
crusader bug
on citrus **74**
Cryptocarya rigida 173
Cryptochaetum iceryae
parasite of scale insects 66
Cryptolaemus montrouzieri
predator, of mealybugs 67
of *Parthenolecanium persicae* 162
of scale insects 63,64,66
of *Pseudococcus longispinus* 162
Cryptophasa melanostigma 128,**141**
Cryptophlebia ombrodelta **182–3**
Cryptoptila immersana 208
cucumber fly
on cucurbits **260–61**
cucumber moth
on cucurbits **260**
cucumbers *see* cucurbit vegetables
cucurbit vegetables
cultivation, N.S.W. 259
pests (listed) 259–60
pests, *Agrotis* spp. 260
Aphis craccivora 265
Aphis gossypii **265**
Asynonychus cervinus 264
Aulacophora hilaris 261–2
Bryobia cristata 266
Creontiades dilutus 265
Dacus cucumis 260–61
Delia platura 261
Graphognathus leucoloma 264
Halotydeus destructor 266
Henosepilachna spp. **262–4**
Monolepta australis 264
Nezara viridula 265
Nysius vinitor 265
Penthaleus major 266
Phakellura indica **260**
Smittia macleayi 261
Tetranychus spp. 265–6
Thrips tabaci 264
Trialeurodes vaporariorum 265
Cudrania javanensis 173
cunjevoi plants
hosts of *Chaetanaphothrips signipennis* 176
cup moth
on apricots **145–6**
currant borer moth
on bush fruits **204–5**
currants (red, black) *see* bush fruits
custard apple trees
hosts of *Ceroplastes rubens* 60
cutworms
on beans **221–2**
on beetroot 241
on carrots 244
on crucifers 253
on cucurbits 260
on grapevines 157
on lettuce 267
on onions 271
on peas 274
on potatoes 281
on rhubarb 241
on silver beet 241
on strawberries 208
on sweet potatoes 288
on tomatoes 294
cyanophyllum scale
on bananas 178
Cydia molesta **126–8**,139
Cydia pomonella **92–6**,117,120,142
cyhexatin
against *Panonychus ulmi* 116

Tetranychus spp. 211
Tetranychus urticae 114,138,144
crop withholding periods 8
Cylas formicarius elegantulus 289–90
Cyphomandra betacea 173

Dactylosternum hydrophiloides 175
Dacus cucumis 260–1
Dacus tryoni **31–5**,100,118,129, 142,157,173,180,187,194,199,294
daisy plants
hosts of *Saissetia oleae* 61
Daktulosphaira vitifolii 160–61
Daphne odora
host of *Coccus hesperidum* 64
Davidsonia pruriens 173
DDT
against *Bostrychopsis jesuita* 196
Brachycaudus persicae 135
Campylomma livida 110
Cryptophasa melanostigma 141
Cydia pomonella 95
Cylas formicarius elegantulus 290
Dihammus vastator 196
Epiphyas postvittana 98
Graphognathus leucoloma 282
Heliothis spp. 292
Heteronychus arator 159,188,209,255,284,296
Leptopius squalidus 40,101
Listroderes obliquus 246,255,268,272,283,296
longicorn borers 42
Maleuterpes spinipes 38
Ophiomyia phaseoli 226
Perperus spp. 101
Phthorimaea operculella 280
scarab beetles 210
Symmetrischema plaesiosema 292
Thrips imaginis 104,130
Thrips tabaci 297
Typhlocyba froggatti 144
crop withholding periods 8
toxicity 6
Delia platura 228,253,261,271–2
demeton-S-methyl
against *Aculops lycopersicae* 300
Aphis craccivora 235,247,275
Aphis gossypii 265
Brachycaudus persicae 135
Brevicoryne brassicae 257
Caliroa cerasi 149
Cavariella aegopodii 246
Dysaphis foeniculus 247
Eriosoma lanigerum 107
Macrosiphum euphorbiae 285,298
Myzus cerasi 151
Myzus persicae 133,285,298
Tetranychus spp. 238,301
Toxoptera spp. 70
crop withholding periods 8
toxicity 6
Deroceras caruanae 212,243,248,270,277
Deroceras reticulatum 212,243,248,270,277
desert lime trees
hosts, of *Biprorulus bibax* 70
of *Bruchophagus fellis* 29
Desiantha caudata 274
Desiantha diversipes 210,255
Diaporthe citri 53
Diaspididae *see* armoured scales
Diaspis bromeliae 185
diazinon
against *Bedellia somnulentella* 289
Biprorulus bibax 71
Delia platura 272
Drosophila spp. 158
Ophiomyia phaseoli 227
Pentalonia nigronervosa 177
Phyllocnistis citrella 28
Pieris rapae 250
Pseudococcus longispinus 162
Spodoptera litura 271
Thrips tabaci 231,272,275
crop withholding periods 8
toxicity 6
Dibrachys cavus 127
dichlorvos
against *Tetranychus lambi* 178
Dichocrocis punctiferalis 128
dicky rice weevil
on citrus 38–9
dicofol
against *Brevipalpus lewisi* 168
Brevipalpus phoenicis 190
Bryobia rubrioculus 115,138
Panonychus citri 81
Polyphagotarsonemus latus 243
Tetranychus spp. 211,238,301
crop withholding periods 8
toxicity 6
dieldrin
against *Asynonychus cervinus* 37
Cosmopolites sordidus 175
toxicity 6
Dihammus vastator 41,160,188,**195–6**
Dilochrosis atripennis **158**
dimethoate
against *Aculops lycopersicae* 300
aphids on strawberries 210
Aphis craccivora 235,247,275
Aphis gossypii 265
Austroasca viridigrisea 234,247,285,297
Biprorulus bibax 71
Brevicoryne brassicae 257
Cavariella aegopodii 246
Dacus cucumis 260–61
Dacus tryoni 34,100,118,129,173,294
Dysaphis foeniculus 247
Eriosoma lanigerum 107
Froggattia olivinia 198
Macrosiphum euphorbiae 285,298
Mictis profana 74
Musgraveia sulciventris 74
Myzus persicae 133,285,298
Ophiomyia phaseoli 226–7
Phaulacridium vittatum 112,275,286
Phyllocnistis citrella 28
Phytomyza syngenesiae 268
Rhizoglyphus echinopus 273
Scolypopa australis 234
Taeniothrips nigricornis 231
Tetranychus spp. 238,301
Thrips tabaci 231,264,275
Toxoptera spp. 70
crop withholding periods 8
injury to citrus 28
toxicity 6
Dindymus versicolor **233–4**,242,257,297
dink bug
on rhubarb 242
Diphucephala sp. **158**, 229
Dirioxa pornia **35**
docks
hosts, of *Leptopius squalidus* 40
of *Myzus persicae* 131
Doratifera spp. **145–6**
dried fruit beetles
on apricots 146
on peaches and nectarines **129–30**
Drosophila spp. **158**,294
ducks
for snail control, in citrus 83
dupla scale
on loquats 121
Duplaspidiotus claviger 121
Dysaphis foeniculus 247
Dysdercus sidae **139**,164
Dysmicoccus brevipes **185**

earwigs
on lettuce **269–70**
egg-fruit caterpillar **292–3**
eggplants
cultivation, N.S.W. 290
pests (listed) 291
pests, *Sceliodes cordalis* **292–3**
Tetranychus spp. 301
Elaeodendron australe
host of *Gascardia destructor* 57
Elateridae 246,256,284,296
elephant weevil
on citrus **37–8**
on grapevines 159
elm trees
hosts of *Cryptophasa melanostigma* 141
Encarsia formosa 235,299
endosulfan
against *Acrocercops chionosema* 182
Agrotis spp. 157,222,244,253,281
Amblypelta nitida 181,184
Chrysodeixis spp. 281
Heliothis spp. 99,292
Homoeosoma vagella 182
Leptoglossus australis 190
Neodrepta luteotactella 183
Phakellura indica 260
crop withholding periods 8
toxicity 6
endrin
toxicity 6
Epimegastigmus brevivalvus
parasite of *Bruchophagus fellis* 29,30
Epiphyas postvittana 25–6,**96–9**, 117,128,141,145,157,208,244
Eremocitrus glauca see desert lime trees
Eriococcus ironsidei 184
Eriophyes ficus 197
Eriophyes sheldoni **76–7**
Eriophyes tristriatus **200–201**
Eriophyidae *see* rust mites
Eriosoma lanigerum **104–7**
Eriosoma pyricola 118
ethion
against *Aonidiella* spp. 52
Brachycaudus persicae 135
citrus rust mites 79
Coccus spp. 64,65
Comstockaspis perniciosus 109,135
Eulecanium pruinosum 143
Lepidosaphes beckii 53
Myzus persicae 133
Parthenolecanium persicae 162
Polyphagotarsonemus latus 80
Pseudococcus longispinus 162
Saissetia oleae 63
crop withholding periods 8
toxicity 6
ethylene dibromide
against *Bruchophagus fellis* 31
Dacus tryoni 173
weevils of strawberries 209
Eucalyptus spp.
hosts, of *Leptopius squalidus* 39
of *Orthorhinus cylindrirostris* 37
Eudocima salaminia 29
Eugenia spp. *see* lillypilly trees
Eulecanium pruinosum 135,143,147
Euplectrus sp. 156
European red mite
on apples 115–6
on plums and prunes 144
Eutinophaea bicristata 39

false wireworms
on carrots 246
on crucifers 256
on parsnips 246
on potatoes 284
on tomatoes 296
fat hen
host, of *Aonidiella aurantii* 48
of *Asynonychus cervinus* 36
fenbutatin oxide
against *Tetranychus urticae* 114,138
fenitrothion
against *Phaulacridium vittatum* 112
toxicity 6
fennel aphid
on carrots 247
fensulfothion
toxicity 6
fenthion
against *Cydia molesta* 127
Dacus tryoni 34,100,118,129,173
Epiphyas postvittana 128,141
Nezara viridula 136
crop withholding periods 8
toxicity 6
ferment flies
on grapes **158**
on tomatoes 294
ferns
hosts of *Ceroplastes rubens* 60
Ficus spp.
hosts, of *Aricerus eichoffi* 196
of *Dacus tryoni* 173
fig bark beetle **196**
fig blister mite **197**
fig fruit borer **194**
fig leaf beetle **195**
fig leafhopper **197**
fig longicorn **195–6**
on citrus 41
on grapevines 160
on passionfruit 188
fig rust mite **197**
fig trees
cultivation, N.S.W. 194
hosts, of *Aonidiella aurantii* 48
of *Coccus hesperidum* 64
pests (listed) 194
pests, *Aricerus eichoffi* **196**
Austroasca australica **197**
Bostrychopsis jesuita **196**
Dihammus vastator **195–6**
Eriophyes ficus **197**
Parasaissetia nigra **197**
Phycomorpha prasinochroa **194**
Poneridia semipullata **195**
figs
hosts, of *Dilochrosis atripennis* 158
pests (listed) 194
pests, *Dacus tryoni* 194
Eriophyes ficus **197**
Phycomorpha prasinochroa **194**
Poneridia semipullata **195**
Rhyncaphytoptus ficifoliae **197**
finger lime trees
hosts, of *Biprorulus bibax* 70
of *Brucophagus fellis* 29
Fiorinia fioriniae 181
fiorinia scale
on avocados 181
fish
toxicity of insecticides to 7–8

flat mites
on beans 238
on citrus **81**
on strawberries 211
flea beetles
on avocados 180
on lettuce 268
on potatoes **284**
on rhubarb 242
on sweet potatoes 290
striped, on crucifers 256
flies, parasitic
of *Agrotis* spp. 222
of *Brachycaudus persicae* 135
of *Epiphyas postvittana* 99
of *Listroderes obliquus* 255
of *Myzus cerasi* 150
of *Myzus persicae* 133
of *Phaulacridium vittatum* 112
flower chafer
on grapevines **158**
Forficula auricularia **269–70**
Formicidae *see* ants
formothion
crop withholding periods 8
toxicity 6
Froggattia oliviana **198**
frosted scale
on apricots 147
on peaches and nectarines 135
on plums and prunes 143
fruit-spotting bug
on avocados 181
on macadamias 183–4
on peaches and nectarines **136**
on plums and prunes 144
fruit-sucking moths
on citrus **28–9**
fruit tree borer
on peaches and nectarines 128
on plums and prunes **141**
Fuller's rose weevil
on beans 229
on citrus **36–7**
on cucurbits 264
on passionfruit 187
on rhubarb 242
on strawberries 210
fruit tree pinhole borer
on apricots **146**
fruit tree root weevil
on apples 100–101
on citrus **39–40**
fruits
hosts, of *Carpophilus* spp. 129
withholding periods after sprays 8
fuchsia plants
hosts of *Phalaenoides glycinae* 155
fumigants
carbon bisulphide, of bean seeds 230
ethylene dibromide, of bananas 173
of strawberry beds 209
hydrocyanic gas, of citrus 18
regulations, N.S.W. 10
fungi
parasites, of *Nysius vinitor* 163
of *Panonychus citri* 81
of scale insects 53, 63
Fusarium coccophilum
parasite, of *Lepidosaphes beckii* 53
of *Unaspis citri* 55

Gardenia spp.
hosts, of *Gascardia destructor* 57
of *Saissetia oleae* 61
garden snails *see* snails
garden symphylid
on beans 238
garlic *see* onions
Gascardia destructor **56–9**,200
Gastrimargus musicus 258
Geloptera porosa 43,102
gherkins *see* cucurbit vegetables
giant grasshopper
on citrus 76
Glover's scale
on citrus **54**
gooseberries *see* bush fruits
grape leaf blister mite **165–7**
grape leaf rust mite **167**
grape phylloxera **160–61**
grapefruit
pests, *Aonidiella aurantii* 49
Dacus tryoni 33
grapefruit trees
pests, *Maleuterpes spinipes* 38
grapes
pests (listed) 154
pests, *Brevipalpus lewisi* **167–8**
Dacus tryoni 157
Dilochrosis atripennis **158**
Drosophila spp. **158**
Dysdercus sidae 164
Epiphyas postvittana 157
Heliothrips haemorrhoidalis 160
Nezara viridula 163
Parthenolecanium persicae **161–2**
Porthesia paradoxa 157
Pseudococcus longispinus **162**
Thrips imaginis 160
grapevine hawk moth *see* hawk moths
grapevine moth **155–6**
grapevine scale **161–2**
on plums and prunes 143
grapevines
cultivation, N.S.W. 154
hosts, of *Agrotis* spp. 221
of *Aonidiella aurantii* 48
of *Orthorhinus cylindrirostris* 37
pests (listed) 154
pests, *Agrotis* spp. 157
Brevipalpus lewisi **167–8**
Calepitrimerus vitis **167**
Colomerus vitis **165–7**
Dihammus vastator 160
Daktulosphaira vitifolii **160–61**
Diphucephala sp. **158**
Epiphyas postvittana 157
Haltica gravida 158
Heliothrips haemorrhoidalis 160
Helix aspersa 168
Hippotion celerio **156**
Heteronychus arator **158–9**
Hyalarcta huebneri 157
locusts and grasshoppers 165
Melampsalta sp. **165**
Monolepta divisa **158**
Nysius vinitor **163**
Orthorhinus cylindrirostris 159
Orthorhinus klugi **159**
Oxycarenus arctatus 164–5
Phalaenoides glycinae **155–6**
Plautia affinis 163
Polyphagotarsonemus latus 168
Porthesia paradoxa 157
Pseudococcus longispinus **162**
Scutiphora pedicellata 164
Theretra oldenlandiae 156
quarantine protection, N.S.W. 154,161
Graphognathus leucoloma
209,228,245,255,264,268,**281–2**,296
grass blue butterfly
on beans **225–6**
grasshoppers
on citrus 76
on grapevines 165
green gum tree katydids
on citrus 76
green lacewings
predators, of citrus whiteflies 68
of scale insects 49,63
of *Pseudococcus longispinus* 162
green looper
on beans **223–4**
green mirids
on beans 231
on carrots 247
on cucurbits 265
on parsnips 247
on passionfruit 189
on peaches 137
on potatoes 286
green peach aphid *see* peach aphids
green plant-hopper
on citrus **74**
green scarab beetle
on beans 229
on grapevines **158**
green stink bug
on beans 234
on grapevines 163
on silver beet 242
on tomatoes 298
green vegetable bug
on beans **232–3**
on citrus 71
on crucifers 257
on cucurbits 265
on grapevines 163
on lettuce 269
on passionfruit 188
on peaches and nectarines 136
on potatoes 285
on silver beet 242
on tomatoes 297
greenhouse thrips
on citrus **43**
on grapevines 160
on passionfruit 188
on persimmons 200
on plums and prunes 142
greenhouse whiteflies
on beans **235–6**
on cucurbits 265
on tomatoes 299
Grevillea spp.
hosts, of *Homoeosoma vagella* 182
of scale insects 65
ground beetles
on crucifers 255
ground weevils
on passionfruit 188
on peas 274
Gryllotalpa spp. 286,299
guava trees
hosts, of *Gascardia destructor* 57
pests 197
guava fruits
pests, *Coscinoptycha improbana* 197

Hadronotus sp.
parasite of *Biprorulus bibax* 71
Halmus chalybeus
predator, of *Aonidiella aurantii* 49
of *Chrysomphalus aonidum* 56
of citrus rust mites 79
of *Gascardia destructor* 57
of *Lepidosaphes beckii* 53
of *Panonychus citri* 81
Halotydeus destructor
243,259,266,270,**275–7**
Halticinae 180,242,268,**284**,290
Haltica gravida **158**
harlequin bug
on beans **233–4**
on crucifers 257
on silver beet 242
on tomatoes 297
Harmonia conformis
69,115,133,135,150,257,265
hawk moths
on grapevines **156**
on sweet potatoes **287–8**
hawthorn plants
hosts, of *Bryobia rubrioculus* 114
of *Caliroa cerasi* 148
of *Comstockaspis perniciosus* 107
of *Eriosoma lanigerum* 105
HCN *see* hydrocyanic acid
Heliothis armiger **219–21**,274
Heliothis punctiger **219–21**,274
Heliothis spp.
28,99,128,207,253,269,291–2
Heliothrips haemorrhoidalis
43,142,160,188,200
Helix aspersa **82–3**,168,239,243,248,270
Hellula hydralis **252**
Hemiberlesia cyanophylli **178**
Hemiberlesia lataniae 177,180
Henosepilachna spp. 229,**262–4**,283,296
heptachlor
against *Cosmopolites sordidus* 175
toxicity 6
Hercinothrips bicinctus **176–7**
Heteronychus arator
158–9,175,188,209,241,255,284,**295–6**
hibiscus plants
hosts of *Saissetia oleae* 61
Hippotion celerio **156**,288
Hippotion scrofa 288
holly plants
hosts, of *Ceroplastes rubens* 60
of *Chrysomphalus aonidum* 56
Homoeosoma vagella **182**
honeydew
produced by aphids 150,177,184,235
by bugs 189
by mealybugs 67,162,190
by scale insects 45,46,57,63,64,65, 66,135,143,161,184,190, 198,200
by whiteflies 68,235
Horogenes cerophaga 251
hoverflies
predators, of *Aphis craccivora* 235
of citrus aphids 69
of *Colomerus vitis* 167
Hyalarcta huebneri **26–7**,157
hydrocyanic acid
fumigation, of citrus 18–19
Hymenia recurvalis **240–41**
Hymenobosmina rapi 251

Icerya purchasi **65–6**
inland katydid *see* katydids
insecticides
crop withholding periods 8
formulation 9
resistance to, of citrus pests 20
poisoning by, symptoms 7
regulations 10
safe storage of 7
safety in use of 5,7
toxicity of 5,6
to birds 8
to bees 8
to fish 7–8
to plants 10
use, on citrus 16–21
Insulaspis gloverii **54**
integrated pest control 47,**95–6**
Iridomyrmex sp.
and scale honeydew 63
island fruit fly
on citrus **35**

Isotenes miserana **24–5**
ivy plants
hosts of *Ceroplastes rubens* 60
Ixeuticus longinquus **81**

jacaranda trees
hosts of *Saissetia oleae* 61
japonica bushes
hosts of *Gascardia destructor* 57

katydids
on citrus **75–6**
on peaches and nectarines **137–8**
on plums and prunes 144
kumquat fruits
pests, *Dacus tryoni* 33
kumquat trees
damage to, by dimethoate 28

ladybirds
predators, of *Aphis citricola* 107
of *Aphis craccivora* 235
of *Aphis gossypii* 265
of *Brachycaudus persicae* 135
of *Brevicoryne brassicae* 257
of *Brevipalpus lewisi* 168
of *Bryobia rubrioculus* 115
of citrus aphids 69
of citrus red mites 81
of citrus rust mites 79
of *Diaspis bromeliae* 185
of mealybugs 67
of *Myzus cerasi* 150
of *Parthenolecanium persicae* 162
of peach aphids 133
of *Pentalonia nigronervosa* 177
of *Pseudococcus longispinus* 162
of scale insects 49,53,56,59,60,63,64,66
of *Tetranychus lambi* 178
of *Tetranychus urticae* 114
Lamprolonchaea brouniana **294**
large auger beetle
on fig trees **196**
large pasture scarab
see pasture white grubs
latania scale
on avocados 180
on bananas 177
laws *see* Acts of Parliament
lead arsenate
against *Cydia pomonella* 95
Epiphyas postvittana 98
leaf case moth
on citrus **26–7**
on grapevines 157
leaf roll virus
aphids as vectors of 285
leaf-eating ladybirds
on beans 229
on cucurbits **262–4**
on potatoes 283
on tomatoes 296
leafhoppers
on citrus 75
leaf-miners
of crucifers 253
of passionfruit 187
of sweet potatoes **289**
leaf-roller caterpillars
on strawberries 208
leeks *see* onions
lemon bud moths
on citrus 27
lemon fruits
pests, *Biprorulus bibax* 71
Dacus tryoni 33,35
Eriophyes sheldoni 77
Polyphagotarsonemus latus 80
lemon trees
damage to, by dimethoate 28
pests, *Aonidiella aurantii* 48
Lepidosaphes beckii **52–4**
Lepidosaphes ulmi **10**
leptocoris bug
on tomatoes 297
Leptocoris mitellata 297
Leptoglossus australis **190**
Leptopius squalidus **39–40**,100–101
lettuce
cultivation, N.S.W. 266
pests (listed) 266–7
pests, *Agrotis* spp. 267
Chrysodeixis spp. 267
Deroceras spp. 270
Forficula auricularia 269–70
Graphognathus leucoloma 268
Halotydeus destructor 270
Halticinae 268
Heliothis spp. 267
Helix aspersa 270
Listroderes obliquus 268
Macrosiphum euphorbiae 269
Milax gagates 270
Monolepta australis 269
Nezara viridula 269
Nysius vinitor 269
Penthaleus major 270
Phaulacridium vittatum 269
Phytomyza syngenesiae **267–8**
Spodoptera litura 267
Tetranychus spp. 270
Thrips tabaci 269
light-brown apple moth *see* apple moths
lillypilly trees
hosts, of *Ceroplastes rubens* 60
of *Ceroplastes sinensis* 60
of *Gascardia destructor* 57
lime sulphur
against *Aculus cornutus* 138
Brevipalpus lewisi 168
Bryobia rubrioculus 114
Calepitrimerus vitis 167
Colomerus vitis 167
Comstockaspis perniciosus 109,135
Eriophyes sheldoni 77
Eriophyes tristriatus 200
Phytoptus pyri 119
Rhizoglyphus echinopus 273
Unaspis citri 19,42,56
lindane
against *Agrotis* spp. 157,222,253,281
Brachycaudus persicae 135
Caedicia spp. 76
Elateridae 256
Eriosoma lanigerum 107,284
Forficula auricularia 270
Heteronychus arator 209,284
Listroderes obliquus 255,296
Myzus persicae 133
Tenebrionidae 256
crop withholding periods 8
toxicity 6
Lindingaspis rossi **198**
Lindorus lophantae
predator of *Aonidiella aurantii* 49
Liriomyza chenopodii 241
Listroderes obliquus
242,245,**253–5**,268,272,283,296
locusts
on citrus 76
on grapevines 165
loganberries *see* berry fruits
longicorn borers
on citrus **41–2**
long-tailed mealybug
on citrus 66,67
on grapevines **162**
on pears 118
loopers
on beans **223–4**
on crucifers 252
on lettuce 267
on potatoes 281
on silver beet 241
on strawberries 207
on tomatoes 293
loquat trees
pests, *Duplaspidiotus claviger* 121
loquats
pests, *Dacus tryoni* 33,120
lucerne blue butterfly
see grass blue butterfly
lucerne plants
hosts, of *Graphognathus leucoloma* 281
of *Nezara viridula* 71,136
of *Zizina labradus* 225
lucerne leaf-roller
on carrots 244
lures *see* attractants
Lycium sp. *see* boxthorn plants

macadamia felted coccid 184
macadamia flower caterpillar **182**
macadamia leaf-miner **182**
macadamia nut borer **182–3**
macadamia nut crops
distribution, N.S.W. 181
macadamia nut tees
pests (listed) 182
pests, *Acrocercops chionosema* **182**
Eriococcus ironsidei 184
Neodrepta luteotactella **183**
Toxoptera citricidus 184
macadamia nuts
pests (listed) 182
pests, *Amblypelta nitida* 183–4
Cryptophlebia ombrodelta **182–3**
Homoeosoma vagella **182**
macadamia twig girdler **183**
Macrocentrus ancylivorus 127
Macrosiphum euphorbiae
210,242,269,275,**285**,298
magnesite (insecticide)
against *Acanthoscelides obtectus* 230
maize plants
hosts of *Agrotis* spp. 222
maize weevil
on apples 102
maldison
against *Aculops persicae* 300
Amblypelta nitida 136
Aonidiella spp. 52
Aphis gossypii 265
Aulacophora hilaris 262
Austroasca viridigrisea 234,247,285
Austropeplus sp. 74
Biprorulus bibax 71
Brachycaudus persicae 135
Brevicoryne brassicae 257
Caedicia spp. 76,138
Caliroa cerasi 117–8,149
Carpophilus spp. 130
Chaetanaphothrips orchidii 44
Chaetanaphothrips signipennis 176
Chrysomphalus dictyospermi 181
Coccus spp. 64,65
Creontiades dilutus 189,231
Dacus tryoni 34,35
Drosophila spp. 294
Dysmicoccus brevipes 185
Eulecanium pruinosum 143
Froggattia olivinia 198
Gascardia destructor 59
grasshoppers 76,165
Heliothrips haemorrhoidalis 43,200
Henosepilachna spp. 264
Hyalarcta huebneri 27
Icerya purchasi 66
Ixeuticus longinquus 81
Lepidosaphes beckii 53
locusts 76,165
mealybugs 67
Mictis profana 74
Musgraveia sulciventris 74
Nezara viridula 136,233
Nysius vinitor 136,163, 211,247,272,285
Oxycarenus arctatus 164–5,181
Parthenolecanium persicae 162
Phyllocnistis citrella 28
Pieris rapae 250
Pseudococcus longispinus 162
Saissetia oleae 63
Taeniothrips nigricornis 231
Teleogryllus commodus 211,258
Thrips imaginis 210
Thrips tabaci 231,264,275
Toxoptera spp. 70
Trialeurodes vaporariorum 235
crop withholding periods 8
injury, to citrus 34
toxicity 6
Maleuterpes spinipes **38–9**
mancozeb
against citrus rust mites 79
Mandalotus sp. 188
mandarin fruits
pests, *Dacus tryoni* 33
mandarin trees
pests, *Ceroplastes rubens* 60
maneb
against citrus rust mites 79
mango trees
hosts, of *Ceroplastes rubens* 60
of *Gascardia destructor* 57
Maruca testulalis **224–5**
mauve pittosporum scale
on apples **109–10**
mealybugs
on citrus **66–7**
on passionfruit 190
Mediterranean fruit fly
on citrus **35–6**
Melaleuca spp.
hosts of *Ceroplastes sinensis* 60
Melampsalta sp. **165**
Melanagromyza apii **245**
melanose fungus
on citrus 29, 42
melon aphid
on cucurbits **265**
melon plants
hosts of *Saissetia oleae* 61
melons *see* cucurbit vegetables
Merophyas divulsana 244
metallic flea beetles
on grapevines **158**
metallic shield bug
on almonds 139
on grapevines 164
Metaphycus helvolus
parasite of black scale 31
Metaphycus lounsburyi
parasite of black scale 63
methamidophos
crop withholding periods 8
toxicity 6
methidathion
against *Aonidiella* spp. 52
Ceroplastes rubens 60
Comstockaspis perniciosus 109
Cydia pomonella 95,117
Desiantha diversipes 210
Epiphyas postvittana 99
Gascardia destructor 59
Nysius vinitor 285

crop withholding periods 8
toxicity 6
methiocarb
toxicity 6
methomyl
against *Chrysodeixis* spp. 207
Cryptoptila immersana 208
Epiphyas postvittana 208
Heliothis spp. 207,221,274,292
Maruca testulalis 225
Myzus persicae 133
Pieris rapae 250
Spodoptera litura 208
crop withholding periods 8
toxicity 6
methyl bromide
against *Bruchophagus fellis* 31
mevinphos
against *Brevicoryne brassicae* 257
Chrysodeixis spp. 224,252,281
Creontiades dilutus 189,231
Heliothis spp. 221,253,274
Hymenia recurvalis 240
Myzus cerasi 151
Nezara viridula 233
Nysius vinitor 136,163, 211,247,272
Pieris rapae 250
Zizina labradus 226
crop withholding periods 8
toxicity 6
Microcitrus australasica
see finger lime trees
Microcitrus australis
see Australian round lime
Mictis profana **74**
Milax gagates 212,239,243,248,270,277
mineral oils (insecticides)
see petroleum oils
mites
on citrus **76–81**
predators, of *Brevipalpus lewisi* 168
of citrus rust mites 79
of *Colomerus vitis* 167
of *Panonychus citri* 81
of *Tetranychus urticae* 114,211
miticides *see* acaricides
mole cricket
on potatoes 286
on tomatoes 299
monocrotophos
crop withholding periods 8
toxicity 6
Monolepta australis **43**,175,180,188,264,269
monolepta beetles
on avocados 180
on bananas 175
on citrus **43**
on cucurbits 264
on lettuce 269
on passionfruit 188
small, on grapevines **158**
Monolepta divisa **158**
Monophlebidae *see* soft scales
Musgraveia sulciventris **71–4**
mussel scales
see apple mussel scale; purple scale
Mythimna convecta **288**
Myzus cerasi **149–51**
Myzus persicae **131–3**,139,210,242,257,285,298

Nabis capsiformis 231
naled
crop withholding periods 8
toxicity 6
native olive trees
hosts, of *Froggattia olivinia* 198
nectarine crops
distribution, N.S.W. 125
nectarine fruits
pests (listed) 125
pests, *Amblypelta nitida* 136
Caedicia spp. 137–8
Carpophilus spp. 129
Creontiades dilutus **137**
Cydia molesta **126–8**
Dacus tryoni 129
Dichocrocis punctiferalis 128
Epiphyas postvittana 128
Heliothis spp. 128
Nezara viridula 136
Nysius vinitor 136
Phaulacridium vittatum 137
Porthesia paradoxa 128
Thrips imaginis 130
nectarine trees
growth and development 125
pests (listed) 125
pests, *Aculus cornutus* **138**
Brachycaudus persicae 133
Caedicia spp. 137–8
cicadas **137**
Comstockaspis perniciosus 135
Cryptophasa melanostigma 128
Cydia molesta **126–8**
Eulecanium pruinosum 135
Myzus persicae **131–3**
Otiorhynchus cribricollis 130
Phaulacridium vittatum 137
Tetranychus urticae 138
Thrips imaginis 130
Nectria spp.
parasites of scale insects 63
nematodes
parasites of *Phaulacridium vittatum* 112
Neodrepta luteotactella **183**
Nezara viridula 71,136,163, 188,**232–3**,242,257,265,285,297
nicotine insecticides
against *Brevicoryne brassicae* 257
Ophiomyia phaseoli 226
nigra scale
on figs **197**
Notelaea longifolia 198
Nysius vinitor 74,136,147, **163**,189,211,233,242,247,257, 265,269,272,285,297

Oechalia schellenbergii 156
Oiketicus elongatus **179**
oils (insecticides) *see* petroleum oils
oleander plants
hosts, of *Coccus hesperidum* 64
of *Gascardia destructor* 57
of *Saissetia oleae* 61
olive lace bug **198**
olive parlatoria scale **199**
oleander scale
on persimmons 200
olive trees
cultivation, N.S.W. 198
hosts, of *Aonidiella aurantii* 47
of *Saissetia oleae* 61
pests, *Aonidiella aurantii* 199
Froggattia olivinia **198**
Lindingaspis rossi **198**
Parlatoria oleae **199**
Saissetia oleae 198
olives
pests, *Aonidiella aurantii* 199
Parlatoria oleae 199
omethoate
crop withholding periods 8
toxicity 6
onion maggot
on beans 228
on crucifers 253
on cucurbits 261
on onions 271–2
onion thrips
on beans 231
on citrus 44
on crucifers 256
on cucurbits 264
on lettuce 269
on peas 275
on potatoes 284–5
on tomatoes 296–7
onions (*and* related crops)
cultivation, N.S.W. 270
pests (listed) 270–1
pests, *Agrotis* spp. 271
Delia platura 271–2
Listroderes obliquus 272
Nysius vinitor 272
Rhizoglyphus echinopus 273
Spodoptera litura 271
Thrips tabaci 272
Ophiomyia phaseoli 226–7
orange fruit borer 24–5
orange fruits
hosts of *Dilochrosis atripennis* 158
pests, *Aonidiella aurantii* 45
Dacus tryoni 33, 35
fruit-sucking moths 28
leafhoppers 75
mealybugs 67
rust mites 78
snails 82
Thrips tabaci 44
orange trees
damage to, by dimethoate 28
pests, *Aonidiella aurantii* 45
Eriophyes sheldoni 77
Heliothrips haemorrhoidalis 43
Maleuterpes spinipes 38
Panonychis citri 81
Orchamoplatus citri 68
Orcus australasiae
predator, of *Aonidiella aurantii* 49
of *Chrysomphalus aonidum* 56
organochlorine insecticides 5
poisoning by, symptoms of 7
use, on citrus 20
organophosphorus insecticides 5
against *Aonidiella aurantii* 51–2
Eriosoma lanigerum 107
Gascardia destructor 59
Orchamoplatus citri 68
poisoning by, symptoms of 7
use, on citrus 19
Orgilus lepidus 280
oriental fruit moths
on almonds 139
on peaches and nectarines **126–8**
Orthorhinus cylindrirostris **37–8**,159
Orthorhinus klugi **159**
Orthreis spp. **28–9**
Otiorhynchus cribricollis **40**,130
Oxycarenus arctatus **136**,164–5,181
oxythioquinox
crop withholding periods 8
toxicity 6

Paddy's lucerne
host of *Asynonychus cervinus* 36
painted apple moth *see* apple moths
pale cotton stainer
on almonds 139
on grapevines 164
palm plants
hosts, of *Chrysomphalus aonidum* 56
of *Coccus hesperidum* 64
Panonychus citri **80–81**
Panonychus ulmi **115–6**,144
Papilio aegeus aegeus **23–4**
paper nest wasp **31**
Papilio anactus **23–4**
Paraceraptrocerus nyasicus
parasite of scale insects 47,59
Paradisterna plumifera 41,**42**
Parasaissetia nigra **197**
parathion
against *Pseudococcus longispinus* 162
crop withholding periods 8
toxicity 6
parathion methyl
crop withholding periods 8
toxicity 6
Parlatoria oleae **199**
Parlatoria pittospori **109–10**
parsley
cultivation, N.S.W. 243
pests (listed) 244
parsnip seed wasps 245
parsnips
cultivation, N.S.W. 243
pests (listed) 244
pests, *Austroasca viridigrisea* 247
Creontiades dilutus 247
Graphognathus leucoloma 245
Listroderes obliquus 245–6
Rhizoecus falcifer 247
Systole sp. 245
Tenebrionidae 246
Parthenolecanium persicae 143,**161–2**
Passiflora foetida 173
passionfruit crops
cultivation, N.S.W. 186
passionfruit vines
hosts, of *Agrotis* spp. 221
of *Creontiades dilutus* 137
of *Hercinothrips bicinctus* 176
of *Perperus lateralis* 40
of *Saissetia oleae* 61
pests (listed) 186
pests, Agromyzidae 187
Asynonychus cervinus 187
Brevipalpus phoenicis 190
Coccus hesperidum 190
Creontiades dilutus 189
Dihammus vastator 188
Heliothrips haemorrhoidalis 188
Heteronychus arator 188
Mandalotus sp. 188
mealybugs 190
Monolepta australis 188
Nysius vinitor 189
Perperus lateralis 188
Saissetia oleae 189
Scolypopa australis **189**
passionfruits
pests (listed) 186
pests, *Dacus tryoni* 187
Heliothrips haemorrhoidalis 188
Leptoglossus australis 190
mealybugs 190
Monolepta australis 188
Nezara viridula 188
Nysius vinitor 189
passionvine bug **190**
passionvine hopper **189**
on beans 234
on citrus 75
passionvine mite 190
pasture plants
hosts, of *Aphis craccivora* 234–5
of *Desiantha diversipes* 255
of false wireworms 246
of *Heteronychus arator* 296
of *Phaulacridium vittatum* 286
of *Rhopaea magnicornis* 284
of wireworms 246
pasture white grubs
on pineapples **185**
on potatoes 284
pea plants
cultivation, N.S.W. 273
pests (listed) 273–4

pests, *Agrotis* spp. 274
Aphis craccivora 275
Deroceras spp. 272
Desiantha caudata **274**
Halotydeus destructor **275–7**
Heliothis spp. 274
Macrosiphum euphorbiae 275
Milax gagates 277
Penthaleus major **275–7**
Phaulacridium vittatum 275
Prosayleus dispar 274
Thrips tabaci 275
peach aphids
black, **133–5**
on almonds 139
on plums and prunes 143
green, **131–3**
on almonds 139
on crucifers 257
on potatoes 285
on rhubarb 242
on silver beet 242
on strawberries 210
peach crops
distribution, N.S.W. 125
peach fruits
hosts, of *Dirioxa pornia* 35
pests (listed) 125
pests, *Amblypelta nitida* 136
Caedicia spp. 137–8
Carpophilus spp. 129
Creontiades dilutus **137**
Cydia molesta **126–8**
Dacus tryoni 129
Dichocrocis punctiferalis **128**
Epiphyas postvittana 128
Heliothis spp. 128
Nezara viridula 136
Nysius vinitor 136
Oxycarenus arctatus 136
Phaulacridium vittatum 137
Porthesia paradoxa 128
peach silver mite **138**
peach trees
growth and development 125
pests (listed) 125
pests, *Aculus cornutus* **138**
Brachycaudus persicae 133
Bryobia rubrioculus 138
Caedicia spp. 137–8
cicadas **137**
Comstockaspis perniciosus 135
Cryptophasa melanostigma 128
Cydia molesta **126–8**
Eulecanium pruinosum 135
Myzus persicae **131–3**
Otiorhynchus cribricollis 130
Phaulacridium vittatum 137
Pseudaulacaspis pentagona **135–6**
Tetranychus urticae 138
Thrips imaginis 130
peach white scale
on peaches and nectarines **135–6**
pear and cherry slug
on cherries **148–9**
on pears 117–8
on plums and prunes 142
pear crops
distribution, N.S.W. 116
pear fruits
pests (listed) 117
pests, *Cydia pomonella* 117
Dacus tryoni 118
Epiphyas postvittana 117
Pseudococcus longispinus 118
withholding periods after sprays 8
pear leaf blister mite 119
pear root aphid 118
pear trees
growth and development 116
hosts, of *Aonidiella aurantii* 48
of *Bryobia rubrioculus* 114
of *Cydia pomonella* 92
pests (listed) 117
pests, *Bryobia rubrioculus* 119
Caliroa cerasi 117–8
Comstockaspis perniciosus 118
Eriosoma pyricola 118
Phytoptus pyri 119
Pseudococcus longispinus 118
Tetranychus urticae 119
Thrips imaginis 118
Pentalonia nigronervosa **177**
Penthaleus major 243,259,266,270,**275–7**
Perperus lateralis **40**,188
Perperus spp. **101**
persimmon fruits
pests, *Aspidiotus nerii* 200
Dacus tryoni 199
Gascardia destructor 200
Heliothrips haemorrhoidalis 200
persimmon trees
cultivation, N.S.W. 199
hosts, of *Gascardia destructor* 57
pest management (concept)
see integrated pest control
pesticides
labels, compliance with viii
petroleum oils
against *Aonidiella* spp. 51–2
Aulacaspis rosae 206
Bryobia rubrioculus 115,138
Ceroplastes sinensis 61
Coccus spp. 64,65
Comstockaspis perniciosus 109,135
Diaspis bromeliae 185
Eriococcus ironsidei 184
Eriophyes sheldoni 77
Eulecanium pruinosum 143
Gascardia destructor 59,200
Icerya purchasi 66
Lepidosaphes beckii 53–4
mealybugs 67
Orchamoplatus citri 68
Panonychus ulmi 116
Parasaissetia nigra 197
Parthenolecanium persicae 162
Tegolophus australis 79
compatibility with pesticides 18
crop withholding periods 8
damage by, to citrus trees 18
formulation, specifications 16–17
insecticidal mechanisms 18
physical properties 17
uses, on citrus 16–18
Phakellura indica **260**
Phalaenoides glycinae **155–6**
Phaulacridium vittatum **111–2**, 137,144,211,258,269,275,286,299
Pheidole sp.
parasites of *Brucophagus fellis* 30
pheromones 48,96
Philomastix macleaii **205**
phosmet
crop withholding periods 8
toxicity 6
phosphamidon
crop withholding periods 8
toxicity 6
Phthorimaea operculella **278–81**,292
Phycomorpha prasimochroa **194**
Phyllocnistis citrella **28**
Phyllocoptruta oleivora **78–9**
Phyllotreta nemorum 256
Phylloxera vastatrix see Daktulosphaira vitifolii; grape phylloxera
Phytomyza syngenesiae **267–8**
Phytoptus pyri 119
Phytoseius persimilis 211
Pieris rapae 241,**249–50**
pineapple crops
distribution, N.S.W. 184
pineapple decline 184
pineapple mealybug **185**
pineapple plants 184
pests, *Diaspis bromeliae* **185**
Dysmicoccus brevipes **185**
Rhopaea spp. **185**
pineapple scale 185
pineapple wilt 185
pink wax scale
on citrus **60**
pirimicarb
against *Brachycaudus persicae* 135
Eriosoma lanigerum 107
Myzus persicae 133
crop withholding periods 8
pirimiphos-ethyl
against *Cosmopolites sordidus* 175
toxicity 6
pitted apple beetle
on apples 102
on citrus 43
pittosporum longicorn
on citrus **41**
Pittosporum spp.
hosts, of *Ceroplastes rubens* 60
of *Gascardia destructor* 57
of *Icerya purchasi* 65
Plaesius javanus 175
plague thrips
on apples **102–4**
on berry fruits 205
on bush fruits 205
on citrus 44
on grapevines 160
on peaches and nectarines 130
on pears 118
on plums and prunes 142
on strawberries 210
planaria
parasites of *Cosmopolites sordidus* 175
plane trees
hosts of *Cryptophasa melanostigma* 141
Planococcus citri 66,67
Platyomus lividigaster 69,107
Plautia affinis 163,234,242,298
plum trees
cultivation, N.S.W. 140
hosts, of *Myzus persicae* 131
of *Otiorhynchus cribricollis* 40
pests (listed) 140–41
pests, *Anoplongathus* spp. 142
Brachycaudus persicae 143
Bryobia rubrioculus 144
Caedicia simplex 144
Caliroa cerasi 142
Comstockaspis perniciosus 143
Chryptophasa melanostigma 141
Epiphyas postvittana 141
Eulecanium pruinosum 143
Heliothrips haemorrhoidalis 142
Panonychus ulmi 144
Parthenolecanium persicae 143
Phaulacridium vittatum 112,144
Tetranychus urticae 144
Thrips imaginis 142
plums
pests (listed) 140–41
pests, *Amblypelta nitida* 144
Anoplognathus spp. 142
Caedicia simplex 144
Cydia pomonella 142
Dacus tryoni 142
Epiphyas postvittana 141
Phaulacridium vittatum 144
Plutella xylostella **250–1**
pod-sucking bug
on beans 233
Polistes spp. **31**
Polyphagotarsonemus latus **79–80**,168,242–3,266,286
Polyrachis ammon 31
pome fruit trees
hosts of *Tetranychus urticae* 113
pests (listed) 90
pome fruits
hosts of *Cydia molesta* 126
pests (listed) 90
withholding periods after sprays 8
Poncirus trifoliata
host, of *Biprorulus bibax* 70
of *Comstockaspis perniciosus* 107
of *Panonychus citri* 81
Poneridia semipullata **195**
Porthesia paradoxa **128**,157
potassium permanganate
use, on citrus 42
potato aphid **285**
on lettuce 269
on peas 275
on rhubarb 242
on silver beet 242
on strawberries 210
on tomatoes 298
potato moth **278–80**,292
potato plants
cultivation, N.S.W. 277
hosts, of *Aculops lycopersicae* 299
pests (listed) 278
pests, *Agrotis* spp. 281
Austroasca viridigrisea 285
Chrysodeixis spp. 281
Creontiades dilutus 286
Elateridae 284
Graphognathus leucoloma **281–2**
Halticinae **284**
Henosepilachna spp. 283
Heteronychus arator 284
Listroderes obliquus 283
Macrosiphum euphorbiae **285**
Myzus persicae 285
Nezara viridula 285
Nysius vinitor 285
Phaulacridium vittatum 286
Phthorimaea operculella **278–81**
Polyphagotarsonemus latus 286
Rhopaea magnicornis 284
termites 286
Tetranychus spp. 286
Thrips tabaci 284–5
potatoes
hosts of *Creontiades dilutus* 137
pests (listed) 278
pests, *Graphognathus leucoloma* 281–2
Gryllotalpa spp. 286
Phthorimaea operculella **278–81**
Rhopaea magnicornis 284
Tenebrionidae 284
termites 286
Prays parilis
on citrus 27
Pristhecanthus papuensis see assassin bugs
Procacus dubius 258
promecarb
against *Gascardia destructor* 59
crop withholding periods 8
toxicity 6
propargite
against *Tetranychus urticae* 114,138
crop withholding periods 8
Prosayleus dispar 274
prune scale *see* frosted scale
prune trees
cultivation, N.S.W. 140
pests (listed) 140–41
pests, *Anoplagnathus* spp. 142
Brachycaudus persicae 143
Bryobia rubrioculus 144
Caedicia simplex 144
Caliroa cerasi 142
Comstockaspis perniciosus 143
Cryptophasa melanostigma 141
Epiphyas postvittana 141

Eulecanium pruinosum 143
Heliothrips haemorrhoidalis 142
Panonychus ulmi 144
Parthenolecanium persicae 143
Phaulacridium vittatum 144
Tetranychus urticae 144
Thrips imaginis 142
Typhlocyba froggatti 144
prunes
pests (listed) 140–41
pests, *Amblypelta nitida* 144
Anoplognathus spp. 142
Caedicia simplex 144
Cydia pomonella 142
Dacus tryoni 142
Pseudaulacaspis pentagona **135–6**
Pseudococcidae *see* mealybugs
Pseudococcus calceolariae 66,67
Pseudococcus longispinus 66,67,118,**162**
Pteromalus puparum 250
pumpkin beetle
on cucurbits **261–2**
pumpkins *see* cucurbit vegetables
purple scale
on citrus **52–4**
pyrethroids 5
against *Drosophila* spp. 158
Polistes spp. 31
toxicity 6

quarantine regulations
bananas 172,175
grapevines 154,161,177
Queensland fruit fly
on apples 100
on avocados 180
on bananas 173
on capsicums 294
on citrus **31–5**
on figs 194
on grapes 157
on passionfruit 187
on peaches and nectarines 129
on pears 118
on persimmons 199
on plums and prunes 142
on tomatoes 294
Queensland nuts *see* macadamia nuts
quinces
hosts of *Cydia molesta* 126
pests (listed) 120
pests, *Cydia pomonella* 120

radishes *see* cruciferous vegetables
raspberries *see* bush fruits
rats
predators of snails 82
red currants *see* bush fruits
red-legged earth mite
on beetroot 243
on crucifers 259
on cucurbits 266
on lettuce 270
on peas **275–7**
on silver beet 243
red scale *see* California red scale
Repsimus manicatus 142
reticulated slug *see* slugs
Rhinaria perdix **208–9**
Rhizobius ventralis
predator of scale insects 56,63,64,66
Rhizoecus falcifer 247
Rhizoglyphus echinopus **273**
Rhopaea magnicornis 284
Rhopaea spp. **185**
rhubarb
cultivation, N.S.W. 239
pests (listed) 239–40
pests, *Agrotis* spp. 241
Asynonychus cervinus 242
Creontiades sp. 242
Deroceras spp. 242
Eriophyidae 243
flea beetles 242
Helix aspersa 243
Heteronychus arator 241
Macrosiphum euphorbiae 242
Milax gagates 243
Myzus persicae 242
Tetranychus spp. 243
Rhyncaphytoptus ficifoliae **197**
Rhyparida sp. 180
rice weevil
on apples 102
Riptortus serripes 233
Rodolia cardinalis 65,66
rootstocks
of apples, woolly aphid resistant 106
peach, of stone fruits, aphid attack 133
rose plants
hosts, of *Aonidiella aurantii* 48
of *Aulacaspis rosae* 206
of *Myzus persicae* 131
of *Otiorhynchus cribricollis* 40
rose scale
on berry fruits **206**
Ross's black scale
on olives 198
rotenone
against *Chrysodeixis* spp. 207
Heliothis spp. 207
Phthorimaea operculella 281
Spodoptera litura 208
crop withholding periods 8
toxicity 6
rough lemon trees
damage to, by *Bruchophagus fellis* 29
Rumex spp. *see* docks
rust mite
on rhubarb 243
Rutherglen bug
on apricots 147
on beans 233
on carrots 247
on citrus 74
on crucifers 257
on cucurbits 265
on grapevines 163
on lettuce 269
on onions 272
on passionfruit 189
on peaches and nectarines 136
on potatoes 285
on silver beet 242
on strawberries 211
on tomatoes 297

Saissetia oleae **61–3**,189–90,198
San José scale
on almonds 139
on apples **107–9**
on apricots 147
on peaches and nectarines **135**
on pears 118
on plums and prunes 143
Saunders' case moth
on avocados **179**
scale insects
on citrus 44–66
parasites and predators 46–7
Scarabaeidae **185,209–10**
Scelio improcerus 112
Scelioides cordalis **292–3**
Scolypopa australis 75,**189**,234
scrofa hawk moth *see* hawk moths
Scutellista cyanea
predator of scale insects 61,63
Scutigerella immaculata 238
Scutiphora pedicellata **139**,164
Scymnus sp.
predator of *Polyphagotarsonemus latus* 80
seedling bean midge **228**,261
Septobasidium spp.
parasites of *Lepidosaphes beckii* 53
Serangium bicolor
predator, of citrus red mites 81
of citrus rust mites 79
shallots *see* onions
shield bugs
predators, of *Phalaenoides glycinae* 156
of *Poneridia semipullata* 195
Sida rhombifolia see Paddy's lucerne
silver beet
cultivation, N.S.W. 239
pests (listed) 239–40
pests, *Agrotis* spp. 241
Chrysodeixis spp. 241
Dindymus versicolor 242
Halotydeus destructor 243
Helix aspersa 243
Hymenia recurvalis **240–41**
Liromyza chenopodii **241**
Listroderes obliquus 242
Macrosiphum euphorbiae 242
Milax gagates 243
Myzus persicae 242
Nezara viridula 242
Nysius vinitor 242
Penthaleus major 243
Pieris rapae 241
Plautia affinis 242
Polyphagotarsonemus latus 242–3
Spodoptera litura 241
Teleogryllus commodus 242
Tetranychus spp. 243
Siphanta acuta **74**
Sitophilus oryzae 102
Sitophilus zeamais 102
Skeletodes tetrops 41,**42**
slugs
on beans 239
on carrots 248
on lettuce 270
on peas 277
on rhubarb 243
on silver beet 243
on strawberries 212
Smittia macleayi **228**,261
Smynthurodes betae **235**
snails
on beans 239
on carrots 248
on citrus **82–3**
on grapevines 168
on lettuce 270
on rhubarb 243
on silver beet 243
snow scale *see* white louse scale
soap solution (insecticide)
see soda and soap solutions
soda and soap solutions
against *Gascardia destructor* 59
Musgraveia sulciventris 74
soft brown scale
on citrus **64**
on passionfruit 190
soft scales **45–6**,56–66
soldier beetle
on cherries 149
sooty moulds
of apples 106
of bananas 177
of beans 235
of cherries 150
of citrus 45,57,63,64,65,66,67,68
of grapevines 161,162
of macadamias 184
of passionfruit 189,190
of persimmons 200
sow thistles
hosts of *Trialeurodes vaporariorum* 235
Spanish red scale
on avocados 181
speckled longicorn
on citrus 41,**42**
Sphingidae *see* hawk moths
spider mites
on beans **236–8**
on carrots 247
on cucurbits 265–6
on eggplants 301
on lettuce 270
on potatoes 286
on strawberries 211
on sweet potatoes 290
on tomatoes 301
spiders
predators, of *Epiphyas postvittana* 157
spinach beet *see* silver beet
spined citrus bug **70–71**
spine-tailed weevils
on peas **274**
spiraea aphids
on apples 107
Spodoptera litura
208,241,**251–2**,267,271,293
spotted vegetable weevil
see vegetable weevils
spotted wilt virus
Thrips tabaci as vector of 272,284,296
spray-bait *see* bait sprays
sprays
application, techniques 9
recommendations, terminology 9
spur-throated locusts
on citrus 76
squashes *see* cucurbit vegetables
steel blue ladybird *see Halmus chalybeus*
stem-end rot
of citrus 53
Stethorus nigripes 79,81
Stethorus spp. 114,115,238
Stethorus vagans 178
stone fruit trees
hosts, of *Brachycauda persicae* 133
of *Bryobia rubrioculus* 115
pests (listed) 124
stone fruits
hosts of *Cydia molesta* 126
pests (listed) 124
strawberry aphid 210
strawberry fruits
pests (listed) 207
pests, *Heliothis* spp. 207
Heteronychus arator 209
Phaulacridium vittatum 211
strawberry plants
cultivation, N.S.W. 206
pests (listed) 207
pests, *Agrotis* spp. 208
aphids 210
Asynonychus cervinus 210
Brevipalpus spp. 211
Chrysodeixis spp. 207
Cryptoptila immersana 208
Deroceras spp. 212
Desiantha diversipes 210
Epiphyas postvittana 208
Graphognathus leucoloma 209
Heliothis spp. 207
Milax gagates 212
Nysius vinitor 211
Rhinaria perdix **208–9**
scarab beetles **209–10**
Spodoptera litura 208
Teleogryllus commodus 211
Tetranychus spp. 211
Thrips imaginis 210
strawberry spider mite
on bananas **178**
strawberry weevil **208–9**
striped flea beetle *see* flea beetles
Strongylus thoracicus **41**

sulphur (insecticide)
against *Aculops lycopersicae* 300
Brevipalpus lewisi 168
Calepitrimerus vitis 167
citrus rust mites 79
Colomerus vitis 167
Eriophyes ficus 197
Eriophyes sheldoni 77
Polyphagotarsonemus latus 243,266,286
Rhyncaphytoptus ficifoliae 197
rust mites 243
Tetranychus spp. 238,266,301
Unaspis citri 19,56
swede turnips *see* cruciferous vegetables
sweet potato plants
cultivation, N.S.W. 287
pests (listed) 287
pests, *Agrotis* spp. **288**
Bedellia somnulentella 289
Cylas formicarius elegantulus 289–90
Halticinae 290
hawk moths **287–8**
Mythimna convecta 288
Tetranychus spp. 290
sweet potato weevil **289–90**
Swiss chard *see* silver beet
Symmetrischema plaesiosema **292**
symphylids
on beans 238
Synanthedon tipuliformis **204–5**
Systole sp. 245

Taeniothrips nigricornis **230–31**
tar oils
against *Myzus persicae* 133
tea trees *see Melaleuca* spp.
Teia anartoides **99–100**
Tegolophus australis **78–9**
Teleogryllus commodus 211,242,**257–8**,299
Tenebrionidae 246,256,284,296
termites
on potatoes 286
Tersilochus spp. 255
tetradifon
against *Tetranychus lambi* 178
crop withholding periods 8
toxicity 6
Tetranychus lambi **178**
Tetranychus ludeni 211,**236–8**
Tetranychus spp. 243,247,265–6,270,286,290,301
Tetranychus urticae 112–4,119,138,140,144,211,236–8
Theretra oldenlandiae **156**,288
thiometon
against *Macrosiphum euphorbiae* 285
Myzus cerasi 151
Myzus persicae 133,285
crop withholding periods 8
toxicity 6
thrips
predators, of *Brevipalpus lewisi* 168
of *Colomerus vitis* 167
Thrips imaginis 44,**102–4**,118,130,142,160,205,210
Thrips tabaci 44,231,256, 264,269,**272**,275,284–5,296–7
Thyraella collaris 251
Tiracola plagiata **173**
tobacco looper
on beans **223–4**
tobacco plants
hosts, of *Chrysodeixis* spp. 223
tomato fly
metallic-green **294**
tomato russet mite **299–300**
tomato plants
cultivation, N.S.W. 290
pests (listed) 291
pests, *Aculops lycopersicae* 299–300
Agrotis spp. 294
Aphis craccivora 299
Austroasca viridigrisea **297**
Chrysodeixis spp. 293
Dindymus versicolor 297
Elateridae 296
Graphognathus leucoloma 296
Gryllŏtalpa spp. 299
Henosepilachna spp. 296
Heteronychus arator **295–6**
Leptocoris mitellata 297
Listroderes obliquus 296
Macrosiphum euphorbiae 298
Myzus persicae 298
Nezara viridula 297
Nysius vinitor 297
Phaulacridium vittatum 299
Phthorimaea operculella 292
Plautia affinis 298
Spodoptera litura 293
Symmetrischema plaesiosema **292**
Teleogryllus commodus 299
Tenebrionidae 296
Tetranychus spp. 301
Thrips tabaci 296
Trialeurodes vaporariorum 299
tomatoes
pests (listed) 291
pests, *Chrysodeixis* spp. 293
Dacus tryoni 294
Drosophila spp. 294
Heliothis spp. 291–2
Lamprolonchaea brouniana **294**
Phthorimaea operculella 292
Sciliodes cordalis 292–3
withholding periods after sprays 8
tomato stem borer 292
Torbia perficita 76
toxicity data
insecticides 6
Toxoptera aurantii **68–70**
Toxoptera citricidae **68–70**,184
Trialeurodes vaporariorum **235–6**,265,299
trichlorfon
against *Amblypelta nitida* 181,184
crop withholding periods 8
toxicity 6
Trichogramma sp. 95,99
Trichopsidea ostracea 112
trifoliata *see Poncirus trifoliata*
turkey bush
host of *Gascardia destructor* 57
turnips *see* cruciferous vegetables
tussock moths
on grapevines 157
on peaches and nectarines **128**
twenty-eight-spotted ladybird *see* leaf-eating ladybirds
twenty-six-spotted ladybird *see* leaf-eating ladybirds

Unaspis citri **54–6**
Uracanthus cryptophagus 41,**42**

Valanga irregularis 76,165
vamidothion
against *Eriosoma lanigerum* 107
crop withholding periods 8
toxicity 6
vegetable jassid
on beans 234
on carrots 247
on celery 247
on parsnips 247
on potatoes 285
on tomatoes **297**
vegetable weevils
on beets 242
on carrots 245–6
on celery 245–6
on crucifers **253–5**
on lettuce 268
on onions 272
on parsnips 245–6
on potatoes 283
on tomatoes 296
spotted, on crucifers 255
on strawberries 210
vegetables
hosts, of *Carpophilus* spp. 129
of *Myzus persicae* 131
pests, incidence, factors in 216–7
pests, control, principles of 217
vine hawk moth *see* hawk moths
vine weevil
on grapevines 159
vinegar flies *see* ferment flies
virus diseases
of beans, aphid vectors of 235
of carrots, aphid vectors of 246
of *Panonychus citri* 81
of *Pieris rapae* 250
of potatoes, aphid vectors of 285
of tomatoes, aphid vectors of 298
of tomatoes, thrips vectors of 272,296
Thrips tabaci as vector of 272,284,296

walnut blister mite 200–201
walnut trees
cultivation, N.S.W. 200
pests 200
pests, *Eriophyes tristriatus* 200–201
wasp parasites
of *Agrotis* spp. 222
of *Aphis gossypii* 265
of *Biprorulus bibax* 71
of *Brevicoryne brassicae* 257
of *Cydia molesta* 127
of *Cydia pomonella* 95
of *Epiphyas postvittana* 99,157
of *Eriosoma lanigerum* 106
of *Listroderes obliquus* 255
of *Nezara viridula* 232,233
of *Ophiomyia phaseoli* 226
of *Parthenolecanium persicae* 162
of passionfruit leaf-miners 187
of *Pentalonia nigronervosa* 177
of *Phalaenoides glycinae* 156
of *Phaulacridium vittatum* 112
of *Phthorimaea operculella* 280
of *Pieris rapae* 250
of *Plutella xylostella* 251
of scale insects 46–7,60,61,63,64
of *Teleogryllus commodus* 258
of *Trialeurodes vaporariorum* 235,299
wattle trees *see Acacia* spp.
webbing spiders
on citrus **81**
weeds
hosts, of *Aculops lycopersicae* 299
of *Agrotis* spp. 221
of *Aonidiella aurantii* 48
of *Asynonychus cervinus* 36,229
of *Austroasca viridigrisea* 299
of *Cavariella aegopodii* 246
of *Chrysodeixis* spp. 223
of *Epiphyas postvittana* 25,99
of grapevine bugs 163
of *Haltica gravida* 158
of Halticinae 284
of *Hercinothrips bicinctus* 176
of *Hymenia recurvalis* 240
of *Icerya purchasi* 65
of *Leptopia squalidus* 40
of *Nezara viridula* 232
of *Nysius vinitor* 136,163,211
of *Oxycarenus arctatus* 136,181
of *Perperis lateralis* 40
of *Phthorimaea operculella* 278
of *Phytomyza syngenesiae* 268
of *Pieris rapae* 249
of *Plutella xylostella* 250
of *Polyphagotarsonemus latus* 79
of *Tetranychus* spp. 236
of *Tiracola plagiata* 173
of *Trialeurodes vaporariorum* 235
white curl grubs
on strawberries **209–10**
white fringed weevil
on beans 228
on carrots 245
on crucifers 255
on cucurbits 264
on lettuce 268
on parsnips 245
on potatoes **281–2**
on strawberries 209
on tomatoes 296
white louse scale
on citrus 19,42,**54–6**
white striped weevil
on citrus 40
on passionfruit 188
white wax scale
on citrus **56–9**
on persimmons 200
willow trees
hosts, of *Cryptophasa melanostigma* 141
wingless grasshopper
on apples **111–2**
on crucifers 258
on lettuce 269
on peaches and nectarines 137
on peas 275
on plums and prunes 144
on potatoes 286
on strawberries 211
on tomatoes 299
wireworms
on carrots 246
on crucifers 256
on potatoes 284
on tomatoes 296
withholding periods
crops, after spraying 8
woolly aphids
on apples **104–7**

Xanthium spinosum see Bathurst burr
Xyleborus saxeseni **146**

yellow peach moth
on peaches and nectarines **128**
yellow scale
on citrus **52**
yellow-winged locust
on crucifers 258
youngberries *see* berry fruits

zebra finches
vectors, of *Aonidiella aurantii* 49
of soft scales 46
zineb
against citrus rust mites 79
Zizina labradus **225–6**
Zosteromyia sp. 99

JOHIMA BOOKS
(02) 687 1922

Insect Pests of Fruit and Vegetables in New South Wales describes the insect, mite, snail and slug pests of the crops listed in the Contents below. The importance, distribution, conditions for infestation, plants attacked, description and life history, injury, dispersal and control (natural and applied) are discussed for each pest.

Contents

Introduction
Safe and effective use of insecticides

Citrus
Orange
Lemon
Grapefruit
Mandarin
Kumquat

Pome fruits
Apple
Pear
Quince
Loquat

Stone fruits
Peach and nectarine
Almond
Plum and prune
Apricot
Cherry

Grape

Tropical fruits
Banana
Avocado
Macadamia
Pineapple
Passionfruit

Fruit and nut trees
Fig
Guava
Olive
Persimmon
Walnut

Trailing berries, bush fruits and strawberry
Loganberry
Boysenberry
Youngberry
Raspberry
Gooseberry
Black and red currants
Strawberry

Vegetables
Bean
Beetroot, silver beet and rhubarb
Carrot, parsnip, celery and parsley
Cruciferous crops
Cucurbit crops
Lettuce
Onion and related crops
Pea
Potato
Sweet potato
Tomato, capsicum and eggplant

ISBN 0 909605 27 0